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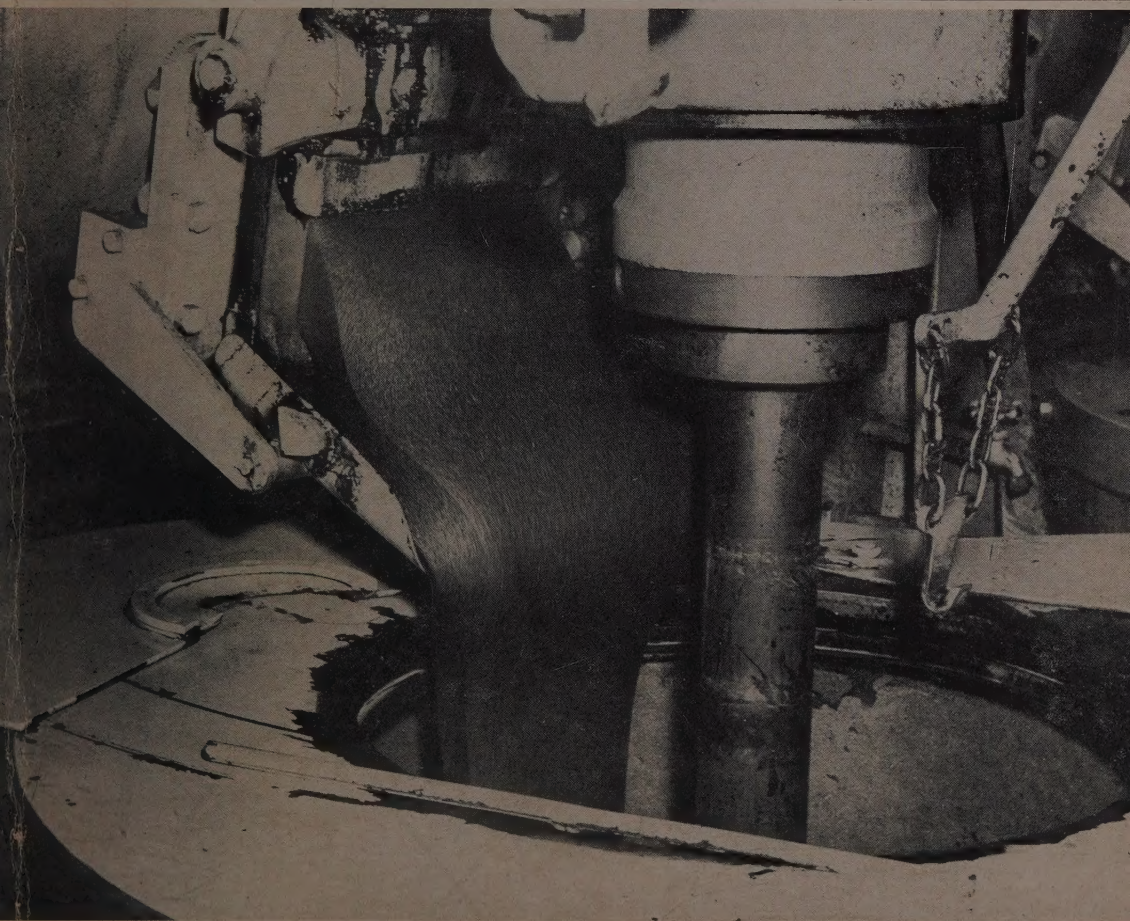
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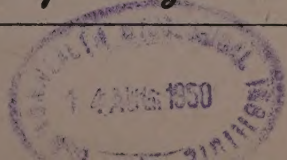
1950

No. 3

Development of the Gillett Process



of Sugar Crystallization



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Hawaiian Sugar Planters' Association
For 1950

The

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Cover Picture—Massecuite pouring into the basket of a low-grade centrifugal.

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Development of the Gillett Process of Sugar Crystallization

By Eugene C. Gillett and William Kenda¹

FOREWORD

To assist in a research project designed to improve techniques in boiling low-grade sugars, the Experiment Station, Hawaiian Sugar Planters' Association, invited Eugene C. Gillett of California and Hawaiian Sugar Refining Corporation Ltd. to come to Hawaii. This report is a detailed discussion and analysis of the experiments he conducted with William Kenda of the Experiment Station, result of which was the development of an improved method of sugar boiling, titled the "Gillett Process of Sugar Crystallization."

Although the Gillett process puts particular emphasis on use of Fondant sugar seed, other processing factors have been stressed equally as much—such features as control of pan circulation, close control of the entire boiling cycle to avoid an increase or decrease in the initially established seed crop, selection of a massecuite purity high enough to grow the maximum crystal crop volume consistent with fluidity requirements, and control of the "boiling down" operation so that the mother liquor will be consistently concentrated to its highest practical density. It is important to remember that a compromise with any of these factors is very apt to nullify, at least partially, the potential benefits of seeding with Fondant sugar.

L. D. BAVER
Director

INTRODUCTION

Since the primary function of the factory low-grade station is to recover as much sugar as possible from molasses, an improvement in the recovery efficiency of that station offers an opportunity for considerable financial benefit.

¹ Eugene C. Gillett, California and Hawaiian Sugar Refining Corporation Ltd., and William Kenda, Experiment Station, Hawaiian Sugar Planters' Association.

For instance, it has been shown in tables prepared by the staff of the Experiment Station of the HSPA that an increase in commercial sugar extraction represented by a two-point drop in final molasses purity is equivalent, at present prices, to more than one dollar per ton of commercial sugar produced. A figure of this size obviously offers the incentive for research along the lines of this project — improvement in low-grade sugar crystallization and molasses exhaustion.

While much has already been done to increase the efficiency of the present factory crystallization process, the present investigation has pointed the way to still further improvements.

By utilizing the knowledge that has been accumulated from previous investigations and applying some of the newer developments resulting from the present project study, an important gain in recovery can be realized.

For example, we feel justified in concluding that it is possible to improve further the proposed boiling procedures so that, in the case of most factories, it is practical to exhaust molasses at least two points below the present levels. This may be done through an application of improved techniques and controls, which requires relatively small additional investment and involves no important change in operating costs.

This investigation, based on the improved techniques suggested in the report "Low-Grade Sugar Crystallization," by E. C. Gillett, not only led to significant practical improvements in low-grade crystallization work, but also clarified many of the important relationships between the several factors that influence the exhaustion potential of molasses. In particular, the importance of maintaining an adequate crystal crop to receive the sucrose available for crystallization and of maintaining proper low-grade massecuite purities above the levels now generally employed in the factories has been substantiated and emphasized.

The writers wish to express their sincere appreciation for the whole-hearted cooperation that was so generously extended by all concerned and, particularly, by the factory personnel who so greatly assisted in carrying out these boiling tests.

SUMMARY OF RESULTS

Thirty-nine test strikes were boiled at four raw sugar factories during this investigation. In all cases, the results showed that, by the adoption of improved techniques and operational controls, worthwhile improvements could be made in the degree of molasses exhaustion, the workability of the low-grade massecuite, and the purity of the low-grade sugar. (Table 1.)

Twenty-eight strikes were boiled at the

Oahu Sugar Company factory, of which 19 are averaged in the general group shown in Table 1. After close scrutiny of the conditions under which these 19 strikes were boiled, cured and purged, it has been concluded that 10 are reasonably representative of the optimum conditions for good low-grade crystallization. This group of 10 was, therefore, listed separately under the classification "Special Group."

TABLE 1

Points Purity Improvement
Over Regular Factory Results

	Low Grade Sugar	Molasses(*)
	(Increase)	(Decrease)
Oahu Sugar Co. General Group.....	3.80	2.01
" " Special Group.....	4.60	2.50
Waialua Agricultural Co.....	10.10	3.27
Ewa Plantation Company.....	3.40	3.49
H. C. & S. Co.....	0.80	1.16

(*) Calculated as reduction in the points actual purity exceeded "Expected Purity."

"Expected Purity" is the designation selected some years ago by the Experiment Station of the HSPA for the refractometer-sucrose purity of a factory molasses which has been given further exhaustion treatment in the laboratory by the crystallization method. That investigation established the fact that the Expected Purity, and hence the exhaustability, varies considerably with the reducing sugar-ash ratio (RS/A) and also depends somewhat on the nature of the non-sugars in the molasses. Inasmuch as the reducing sugar-ash ratio varies from factory to factory and from season to season at a particular factory, valid comparisons of molasses exhaustions can best be made using the Expected Purity for the molasses under consideration as a reference point.

The Experiment Station has prepared a table showing the relationship between Expected Purity and RS/A and also determines, at regular intervals, the correction (Boiling Test Correction) to be applied to this table for each factory. From the table and correction, the Expected Purity for a particular molasses sample may be determined without extended laboratory exhaustion tests, provided the reducing sugar and ash contents are known.

Test strikes were few in number at the other factories. The figures shown in the foregoing summary are averages for three test strikes at Waialua, three at Ewa and five at H. C. & S.

In Tables 2 and 3 are summarized some of the more pertinent comparative data secured during the experimental runs at the individual plantations.

While the results of these tests at the H. C. & S. factory indicate a slight improvement, it is confidently believed that a much greater improvement can be effected at this factory following completion of the planned installation of a mechanical circulator, a streamline bottom in the low-grade seed pan and the installation of the vacuum control instruments necessary for proper operation of this improved technique. In boiling test strikes from which the data were secured, it was found impossible, with the existing pan and lack of control instruments, to produce what was regarded as a good quality low-grade massecuite. We therefore do not consider the results secured in these trials as indicative of what may

be accomplished when satisfactory equipment and controls are used.

CONCLUSION From the results of this preliminary test work, it appears that a saving of at least one dollar per ton of commercial raws produced may be expected by adoption of the improved low-grade boiling technique. This figure is suggested as an average for the annual Hawaiian crop. In the case of some factories where the spread between actual and expected purities is relatively small, the saving naturally would be less. In other cases, a considerably greater saving than one dollar per ton is indicated by the experience gained in this test work.

These improved results may be accomplished by consistently producing a low-grade massecuite that possesses the highest possible molasses exhaustion potential, within limits of practical factory operation. The technique involved in the boiling of such a massecuite, in essence, requires: precise control over the quantity of seed established, adequate and dependable control over crystal growth and selection of the proper

purity of boiling material to obtain the optimum crystal concentration in the finished massecuite.

No major investment is involved in accomplishing these savings; however, some expenditures will be necessary at

Table 2
Oahu Sugar Company, 7/31-9/4/48
General Group, 19 Test Strikes

	Experimental	Regular	Difference
Mass. Purity.....	60.8	58.6	+ 2.2
Crystal Yield (% on Mass. Solids).....	45.5	39.4	+ 6.1
Low-Grade Sugar Purity.....	84.7	80.9	+ 3.8
Final Molasses Purity, Suc./Rds.....	35.07	36.96	+ 1.89
Expected Purity.....	29.81	29.69	.....
Points above Expected Purity.....	5.26	7.27	- 2.01
RS/A Ratio (*).....	1.84	1.87	.....
Hours in Crystallizer.....	56	36	+20

Table 3
Special Group, 10 Strikes
(Experimental strikes used are those most nearly approaching optimum technique)

Oahu Sugar Company, 7/31-9/4/48

	Experimental	Regular	Difference
Mass. Purity.....	61.6	58.1	+ 3.5
Crystal Yield (% on Mass. Solids).....	46.9	38.6	+ 8.3
Low-Grade Sugar Purity.....	85.8	81.2	+ 4.6
Final Molasses Purity, Suc./Rds.....	34.47	37.0	+ 2.53
Expected Purity.....	29.54	29.57	.....
Points above Expected Purity.....	4.93	7.43	- 2.50
RS/A Ratio.....	1.93	1.91	.....
Hours in Crystallizer.....	52	32	+20

Waialua Agricultural Company, 8/21-8/28/48

Mass. Purity.....	56.7	55.4	+ 1.3
Crystal Yield (% on Mass. Solids).....	39.3	34.3	+ 5.0
Low-Grade Sugar Purity.....	82.2	72.1	+10.1
Final Molasses Purity, Suc./Rds.....	35.99	37.60	+ 1.61
Expected Purity.....	33.71	32.05	.....
Points above Expected Purity.....	2.28	5.55	- 3.27
RS/A Ratio.....	1.42	1.70	.....
Hours in Crystallizer.....	51	72	+21

Ewa Plantation Company, 8/29-9/4/48

Mass. Purity.....	56.7	55.4	+ 1.3
Crystal Yield (% on Mass. Solids).....	37.5	32.0	+ 5.5
Low-Grade Sugar Purity.....	75.4	72.0	+ 3.4
Final Molasses Purity, Suc./Rds.....	38.63	42.01	+ 3.38
Expected Purity.....	33.12	33.01	.....
Points above Expected Purity.....	5.51	9.00	- 3.49
RS/A Ratio.....	1.48	1.49	.....
Hours in Crystallizer.....	85	72	+13

Hawaiian Commercial and Sugar Company, 8/21-8/28/48

Mass. Purity.....	64.7	61.4	+ 3.3
Crystal Yield (% on Mass. Solids).....	43.7	36.9	+ 6.8
Low-Grade Sugar Purity.....	75.0	74.2	+ 0.8
Final Molasses Purity, Suc./Rds.....	44.27	45.53	+ 1.26
Expected Purity.....	36.52	36.62	.....
Points above Expected Purity.....	7.75	8.91	- 1.16
RS/A Ratio.....	.82	.81	.....
Hours in Crystallizer.....	134	144	+10

(*) RS/A as used in this report refers to the reducing sugar-ash ratio. Reducing sugar content is determined by the Lane and Eynon volumetric method and the ash content by a direct ignition procedure.

most factories to provide the control instruments and pan circulation facilities required for successful operation of the technique. The writers recommend that adequate mechanical circulators of good

engineering design be installed in all seed pans and that precise vacuum control be provided. As a less satisfactory alternate, adequate steam agitation may be used until circulators can be obtained.

INSTRUMENTS, EQUIPMENT AND TECHNIQUE

BASIC

REQUIREMENTS To obtain better molasses exhaustion and a higher purity low-grade sugar, it is necessary that certain fundamental considerations be satisfied, as follows:

1. *Massecuite Quality Specifications*

- The final massecuite should contain the maximum crystal concentration consistent with fluidity requirements imposed by the crystallizers and centrifugals.
- The average size of the final crystals should be no larger than necessary to insure good drainage at the centrifugals and a reasonably high purity low-grade sugar.
- The massecuite should be free of fine and conglomerated grain and should contain a crop of crystals reasonably uniform in size.

2. *Control Requirements*

- Effective control is necessary over the establishment and growth of the crystal nuclei crop so as to avoid gain or loss of crystal population in a given strike or from strike to strike.
- Effective and consistent control over the supersaturation of the boiling liquor is essential.

A massecuite that satisfies such characteristics of quality and reproducibility may be produced in regular factory operation by observing the following:

- Select a final massecuite purity which is just sufficient to produce a **crystal** yield by weight on solids of approximately 47 per cent. The exact figure for massecuite purity may be determined by calculation, using the SJM formula and substituting in the

formula the yield figure determined locally as optimum and the objective apparent purity expected for the exhausted molasses. (A **crystal** purity of 99° is assumed in this calculation.)

This important relationship will be discussed in detail later in this report.

- As a substitute for the "shocking" or "waiting" method of seed establishment, use the more dependable method of introducing into the graining charge a predetermined amount of fine seed nuclei.
- Provide the massecuite seed pan with the necessary instruments to reliably indicate when the graining charge has reached the supersaturation determined as optimum for seeding.
- Employ a boiling technique that controls the supersaturation of the mother liquor with reasonable accuracy within limits of the metastable zone.

Either a vacuum or absolute pressure regulator is essential for this requirement; also some means of indicating with reasonable accuracy the prevailing supersaturation during boiling is necessary in the massecuite seed pan and desirable on the finishing pans.

- Provide adequate means for producing supplementary pan circulation, independent of the natural circulation produced by boiling.

Either a suitable mechanical circulator or adequate steam agitation coils are necessary to meet this requirement.

- Avoid, if at all possible, boiling levels that exceed a height of $4\frac{1}{2}$ – $5\frac{1}{2}$ feet above the calandria top tube sheet. This is particularly desirable in the case of pans with sluggish natural circulation in which no adequate mechanical circulators have been installed.

SUPPLEMEN- TARY PAN CIRCULATION One of the primary requisites for good pan work centers in the control of supersaturation, particularly during the early period of grain growth. If the supersaturation of the mother liquor is permitted to exceed a certain critical value, false grain and conglomerates will quickly develop in appreciable amounts. Any such occurrence will preclude the production of a good quality final low-grade massecuite, and lead to both higher purity final molasses and lower purity low-grade sugars.

Calandria pans, which are generally used throughout the industry, have the natural (inherent) characteristic of boiling at a relatively fast rate during the early part of the strike where the static head of the massecuite is comparatively low. In practice, this results in a steadily rising supersaturation during the early crystal growth period, since the relatively small aggregate crystal surface area is insufficient to absorb sucrose from the mother liquor as fast as it is made available by the fast evaporating rate. Because of this, it is necessary to purposely retard the rate of evaporation in order to maintain the supersaturation within safe limits during the critical period of early crystal growth.

However, when the pan is thus slowed down, natural circulation has been found to be impaired so much that an independent means of producing supplementary circulation is required. Experience has indicated that either a mechanical circulator or open injection steam

coils under the calandria is needed to provide the required minimum circulation during the period while natural circulation is curtailed for purposes of controlling supersaturation.

The technique involved in controlling supersaturation of pans equipped with mechanical circulators is relatively simple since it may be accomplished merely by periodically shutting off the calandria steam supply. However, in the case of some pans equipped with steam agitation coils, it has been found inadvisable to shut off the calandria steam supply fully during the boiling period, as the steam agitation coils alone are unable to provide the required minimum over-all circulation. Therefore, with the large heating surface ratio normally prevailing in calandria pans, it is not surprising to find that, even with a major reduction in calandria steam pressure, evaporation still proceeds at a rate which builds up supersaturation beyond safe limits. This requires a further regulatory procedure which, in effect, consists of a gradual heating up of the massecuite in order to increase the solubility of sucrose and thus offset the tendency towards rising supersaturation.

Any type circulator of good engineering design, such as the Webre or Smith, which will produce adequate pan circulation, will satisfy the conditions for a mechanical circulator installation. In providing a supplementary means of independent circulation with steam coils, our experience has indicated that two coils are desirable and that they should be placed underneath the calandria and located respectively about $\frac{1}{3}$ and $\frac{2}{3}$ of the distance between the calandria well and the pan wall. The perforations in the coil should look down and be approximately on one inch centers. Perforations may be about $\frac{5}{32}$ inch when supplied with 10-pound exhaust steam. Each coil should deliver approximately 3000

pounds of steam per hour and this amount should be fixed by means of an orifice installed in the steam supply line to the coil.

At the H. C. & S. Company factory it was found that the poor circulation and temperature differences that exist at different levels in a pan with a deep conical bottom make it difficult to control establishment of the seed crop, even when the greatest precautions are taken. As a result of this experience, it is our opinion that, on those seed pans where mechanical circulation is not provided, a streamline bottom should be installed, in addition to the steam agitation coils.

These considerations have been discussed at this point since they have a considerable bearing on the instrument requirements and the boiling procedures, both of which will be discussed in the following sections.

INSTRUMENTS At the present time some few factory pan houses are equipped with sufficient instruments of adequate sensitivity, but in most cases results depend largely upon the skill of the pan man. However, if present results are to be improved and the maximum advantage secured from the crystallization process, it is necessary to refine and standardize both the technique and controls over pan operations and then thoroughly train the pan men to follow the established procedures.

Based on these and similar studies it is our opinion that all low-grade seed pans should be equipped with the instrument controls as outlined in the following paragraphs. Any type or make of instrument that will accomplish the results within desired limits of precision should be satisfactory from the technology standpoint.

1. Boiling Pressure Control

A dependable and accurate control of the boiling pressure is essential to good

pan operation, irrespective of what methods or techniques are used. This boiling pressure control is required in coil pans, calandria pans equipped with circulators and calandria pans not equipped with circulators, regardless of whether or not steam agitation coils are provided.

The sensitivity and requirement for reliability are set by the precise regulation of boiling pressure necessary at the time of seeding and during the early grain growth period. If the boiling pressure is not held substantially constant during seeding and regulated thereafter very near the pre-established optimum levels, it will be impossible to secure consistently the greatest benefits from the techniques. Experience has indicated that a deviation in boiling pressure greater than ± 0.15 inch Hg., or a fluctuation in temperature of more than about $\pm 1^\circ$ F., is undesirable. Either a vacuum regulator or an absolute pressure regulator may be used for this control.

At the Oahu Sugar Company factory the absolute pressure was regulated by controlling the temperature in a pilot pan in which water was boiled at the same pressure as prevailed in the masse-cuite pan vapor space. This method appears to be quite a satisfactory means of controlling absolute pressure.

At Ewa, Taylor vacuum regulators have been installed on the low-grade pans. Although the writers' experience with this type of control instrument was limited, it appeared to adequately meet the requirements for good boiling pressure control during our test runs.

At the H. C. & S. Company, the writers had some experience with A. L. Webre's recently suggested method of vacuum control. This device, in effect, consists of a relief valve which bleeds air into the pan when the vacuum exceeds a set point. While the idea has its merits, the writers had considerable difficulty in

securing a satisfactory regulation and frequent adjustments to the weights had to be made to compensate for the comparatively large change in condenser water requirements during the various stages of boiling. This device does not appear to be sufficiently flexible and sensitive to meet the precise control required by the proposed low-grade boiling technique and it is recommended that the fundamentally sounder method of controlling boiling pressure (by regulating condenser water feed) be used.

2. Automatic Control of Pre-determined Boiling Pressure Cycle

This control is not required for pans equipped with mechanical circulators.

As indicated in a previous section, however, in the case of seed pans in which steam agitation coils are used in lieu of a mechanical circulator, experience has shown that the boiling temperature of the massecuite must gradually be raised at a rate which will prevent any substantial increase in supersaturation during the critical initial grain growth period.

Further, the pan temperature must be held at a relatively high level for a certain period and then gradually reduced to the normal boiling temperature level. This cycle of temperature change is accomplished by regulating the boiling pressure in accordance with a pre-established schedule. The exact rates of change and the time cycle involved must be established by trial on the particular pan that is to be used for boiling low-grade seed.

In a later section, a typical cycle is described and diagrammed. This typical cycle, it is believed, will be found approximately correct for most factory low-grade pans. Substantially, it indicates that shortly after seed has been introduced, the vacuum is uniformly decreased from $25\frac{1}{2}$ inches Hg., at a rate of about 1 inch Hg. in eight minutes, to

21 inches Hg. After reaching 21 inches Hg. the vacuum is held constant for a period (to be determined by experimentation), after which it is increased steadily at a rate of about 1 inch Hg. in 10 minutes, until the boiling level of $25\frac{1}{2}$ inches Hg. is again reached.

This cycle of pressure change must be closely regulated and performed at a uniform rate. Since this cannot be satisfactorily accomplished by hand control of the condenser water supply, an instrument to automatically control these pressure changes in accordance with a pre-established pattern must be provided.

Experience and calculations have indicated that the control of this time-rate cycle of boiling pressure should be performed within an accuracy of ± 0.15 inch Hg.

3. Supersaturation Determination

Consistently dependable control over the massecuite grain crop is an essential in connection with the improvement of low-grade crystallization and molasses exhaustion.

One primary requirement in accomplishing this is an effective regulation of the supersaturation, within limits of the metastable zone, during the seed establishment and early critical grain growth period. To do this it is obviously necessary to have either some suitable index or an exact measurement of the supersaturation.

Observations associated with the boiling of experimental strikes at several raw factories indicate that boiling point elevation may be used as a satisfactory index of supersaturation, provided the pan boiling pressure is held constant. The boiling point elevation was used both for establishing the proper supersaturation at which to introduce the seed charge, and for a guide to regulate pan boiling conditions during the critical period of initial grain growth.

Satisfactory results have been secured with two types of instruments, as follows:

- A two-pen sensitive, spread scale temperature recorder. One pen records the temperature of vapor from a pilot pan that boils water at the same pressure under which the massecuite pan is boiling; the other pen records the temperature of the boiling material in the massecuite pan. The difference between the two records is read to obtain the boiling point elevation.

This difference, of course, indicates solids concentration but also may be used satisfactorily as an arbitrary index of supersaturation, if the boiling pressure is held constant, the graining purity is standardized and the same level of graining charge is used from strike to strike. The proper boiling point elevation for seed introduction and the initial boiling period must, of course, be determined by trial.

- A Leeds and Northrup Micromax, which gives an expanded scale direct reading of the degrees of boiling point elevation. This instrument also requires a temperature measurement of the vapor from a pilot pan boiling water at the massecuite pan pressure, and a temperature measurement of the boiling material in the massecuite pan. The instrument uses resistance thermometers which are very sensitive and dependable.

Further, the large scale on the instrument itself readily permits an accurate reading of the degrees of boiling point elevation. Also, since this scale indicates the BPE directly, less opportunity for misreading by the pan man exists.

In actual trials, however, it is found that either of these two instruments is satisfactory although, in the case of gas bulb thermometers the bulb should be

extra long to provide the necessary sensitivity, as the BPE at time of seeding should be read within an accuracy of about $\frac{1}{2}^{\circ}$ F. The latter type of installation is used at the Oahu Sugar Company factory.

- If good absolute pressure control is provided, another rather simple method which uses a different approach for determining supersaturation may also be used with success. This method uses an absolute pressure gauge which is equipped with a locally pre-determined temperature scale that shows proper pan boiling temperature for seeding at any particular boiling pressure (see p. 17 "Low-Grade Sugar Crystallization," by E. C. Gillett, May, 1948).

Some years ago an instrument was developed by A. L. Holven of the Crockett refinery staff, which measures and records supersaturation directly. This instrument has proved very sensitive and reliable and has been of great assistance in controlling refinery pan operations in a manner such as to maintain supersaturation within safe limits. This instrument, however, is not available on the market at the present time; if it should become so, its use is recommended highly.

4. Record of Variations in Boiling Pressure

To aid supervisory control and to assist in determining causes of irregularities, it is strongly recommended that an accurate record of either the pan boiling pressure or the temperature of the vapor from a pilot pan connected to the massecuite pan be continuously provided. If this record is in terms of boiling pressure the recording chart should be readable within an accuracy of ± 0.15 inch Hg. If the record is in terms of temperature, the chart should be readable within $\pm 1^{\circ}$ F.

While such a record is not absolutely

essential, it is considered a justifiable investment inasmuch as it should facilitate supervisory control and thus minimize irregularities that otherwise creep in and cause higher molasses purities.

5. Other Instruments

The following additional instruments are strongly recommended for installation on the seed pan in order that both the pan men and the supervisors will have a complete record of all important elements that influence pan results:

- A temperature recorder to record continuously the temperature of massecuite within a readable accuracy of $\pm 1^\circ$ F. (If the two-pen recorder discussed under Supersaturation Determination is used, this separate instrument is unnecessary.)
- A pressure-vacuum recorder on the calandria.
- A recording ammeter on the circulator drive motor for those pans equipped with mechanical circulators. To obtain full value from a mechanical circulator installation, an ammeter to measure its drive motor load is essential, and a recording instead of an indicating instrument is strongly recommended because of the potential assistance it affords supervision.
- A mercury column differential pressure gauge that will indicate the massecuite level in the pan. This is quite valuable for accurately determining graining charge volume and final massecuite volume.

SPECIAL EQUIPMENT In addition to these instruments, the following special equipment is also required to use the proposed technique to best advantage.

1. Device for Determining Crystal Concentration in Massecuite

Such a device has been developed for this purpose and is described on page 27

of E. C. Gillett's report "Low-Grade Sugar Crystallization," issued May, 1948.

The apparent volumetric crystal concentration has an important influence on both the fluidity and molasses exhaustion potential of the massecuite. Valuable information for supervision and control of the boiling process may be secured by checking the crystal concentration when the massecuite is first dropped from the pan and also when dropped to the centrifugals for purging.

This test involves filling the extractor barrel of the device with massecuite and then compressing this massecuite with a piston plunger under a pressure of approximately 40 pounds per square inch, which is not sufficient to crush the crystals. The fluid necessary to fill pore spaces, of course, remains in the crystal bed. The percentage reduction in volume is determined by the ratio of the actual distance of the plunger travel to the total barrel depth and this volume reduction has been termed the "shrinkage factor."

The HSPA Experiment Station has one of these devices constructed in accordance with Crockett specifications. Experience with its use on raw factory massecuites indicates that several modifications to the original design of the apparatus may be desirable. These are:

- Provision of means for supplying the heat necessary to prevent the massecuite from losing its initial temperature during the extraction period.
- Enlargement of the massecuite cup sufficiently to obtain from the test a sample of mother liquor which will be large enough for an apparent purity determination.
- Provision of an auxiliary fine screen of approximately 100-mesh and double thickness to prevent extremely fine crystals from passing through into the extracted mother liquor when

testing massecuites from early stages of boiling.

All these modifications appear desirable for a permanent installation. The development and standardization of the design of the apparatus and the method by the Experiment Station appears desirable prior to factory adoption.

2. Equipment for Seed Slurry

Preparation

A suitable mechanical stirring apparatus for making a homogeneous seed slurry from a mixture of dry Fondant sugar and a saturated high purity syrup is required. This equipment consists primarily of a small tank (about five gallons) and a small high speed stirring device, such as the Lightning mixer. The unit developed at the Crockett refinery for preparing Fondant seed slurry is shown in Figure VIII in E. C. Gillett's report, "Low-Grade Sugar Crystallization," issued May, 1948.

About one gallon of seed slurry per 1000 cubic feet of final low-grade massecuite is required and the equipment should have sufficient capacity to mix a fresh batch for each seed strike. The mixing device may be used also to mix the saturated syrup required for this slurry.

3. Massecuite Sampler

A means for conveniently obtaining a sample of massecuite from all low-grade pans would be very helpful.

While not essential, such an arrangement is recommended as a provision that will readily permit sampling the massecuite at any time for purposes of crystal concentration determination. If a larger extraction barrel than presently used for shrinkage determinations is adopted, it is impractical to obtain a sample of the necessary size from the proof stick.

4. Seed Inlet

A direct connection to the bottom of the pan to admit slurry is needed. The line to this pan connection should be

1½ to two inches and should have a quick opening gate valve located at its terminal. A receptacle may be provided also at the terminal to conveniently receive the prepared seed slurry.

5. Pilot Pan

If boiling point elevation is to be used as a means of determining the index of supersaturation, the massecuite pan must be equipped with a suitable pilot pan.

PAN

OPERATIONAL SUPPLY

Not infrequently the writers have observed that all the necessary instruments and procedures designed to improve results in pan work have been provided, yet the anticipated results failed to materialize. In such cases, the difficulty is often traced to irregularities developing from inadequate control of operational materials supplied the pan, such as steam, condenser water, boiling material, and vacuum, so that the instruments and techniques employed may function properly, a minimum control of fluctuations of these supply materials must be exercised. Therefore, the following provisions will require attention.

- Maintenance of a reasonably uniform steam pressure on the pan steam supply line for the calandria, and also the steam agitation coils, if the latter are used.
- Provision for an adequate supply of water for the condenser, and maintenance of this at a reasonably uniform pressure.
- Provisions to continuously insure against presence of sugar crystal in the pan seed material. Also, establishment of controls to maintain pan feed material at a reasonably uniform density.
- Provision of a separate vapor condensing and vacuum system for each low-grade pan. From the standpoint

of good boiling work, central vacuum systems are unsatisfactory. This is especially true in the case of the low-grade seed pan where consistently good results cannot be expected in regular factory practice when boiling pressures are frequently disturbed by the starting and stopping of other pans.

DETAILS OF IMPROVED TECHNIQUE This section outlines the details of the technique proposed for achieving better molasses exhaustion and higher purity low-grade sugar.

1. General Plan—Low-Grade Massecuite Production

It appears to be rather common practice in the raw sugar industry to boil a seed strike and then cut the seed strike into footings so as to produce a total of two to three final strikes from the initial seed. In our boiling tests, both single strikes and cut strikes were boiled. Later work by G. Bromley at Oahu Sugar Company indicated that a triple cut of the seed strike is also practical. Amount of seed used in each case, of course, differs with the amount of final massecuite produced.

In producing a final massecuite of good quality, it is essential that the seed strike be boiled so as to give a high quality seed for the cut strike footings. If a good quality seed strike is produced, no particular difficulty should exist in production of a good final massecuite. The improvement of low-grade work, therefore, centers around the production of a good quality seed strike. Because of this and the fact that, in the initial growth of the seed, much more care is required to conduct the boiling operation, the improved techniques developed for factory low-grades deal primarily with pan manipulations associated with the boiling of the seed strike.

2. Graining Charge Purity

Trials have indicated that the graining charge purity used for the seed strike should be 7–12 points higher than the final massecuite purity. So far, test results show that a spread of about 10 points appears to be near optimum. However, the exact graining charge purity level can best be determined by trial at each factory, since the type of material boiled will have some influence on selection of the proper purity level.

After the optimum graining charge purity has once been determined, there is a distinct advantage to using it consistently in standard factory practice. Deviations in graining charge purity from strike to strike of more than $\pm 1^\circ$ are apt to cause variations in the seed crop population. More frequent purity determinations may be necessary to insure consistent maintenance of the established optimum graining charge purity.

3. Graining Charge Volume

To obtain optimum results consistently, experience indicates that a standard graining charge just sufficient in volume ("when boiled down") to cover the calandria should be used. This is important not only from the standpoint of obtaining as rapidly as possible the most favorable ratio of crystal volume to fluid volume, but also standardization of the graining charge level assures that the thermometer measuring the boiling temperature is not influenced by changes in the static head (such as would occur with varying size of graining charge).

4. Pan Boiling Pressure

It has been frequently observed that factory low-grade massecuites are boiled at a vacuum of 27 inches, or more. Such a high vacuum naturally means that the temperature of the massecuite is relatively low.

Experience of the writers in boiling Soft sugars at refineries has proved that

low temperatures tend to facilitate formation of conglomerates and spontaneous grain. Higher temperatures, on the other hand, reduce such tendencies. It is believed, therefore, that such extremely low boiling temperatures and high vacuums should be avoided in low-grade work. Not only is the quality of the grain crop better controlled but viscosities are somewhat lower at the higher temperatures. Further, when the strike is dropped to the crystallizers for curing, the advantage of a greater temperature drop may be secured during the curing period. If the massecuites are boiled to the same consistency at the higher temperature as would be maintained at the lower temperature, this greater temperature drop should result in better degasification.

All experimental strikes were boiled between 25 and 26 inches vacuum and it is recommended that vacuums higher than 26 inches be avoided.

In the case of pans equipped with mechanical circulators the vacuum may be held at a constant level throughout the entire boiling period. As explained in the previous section, the vacuum must be lowered, however, during the early grain growth period when boiling low-grade seed strikes in a pan equipped with steam coils and no mechanical circulator.

5. Final Massecuite Purity

As will be developed in greater detail later in this report, selection of the proper massecuite purity is an extremely important consideration from the viewpoint of obtaining maximum possible molasses exhaustion. Experimental work during this investigation definitely established that there is a direct relationship between the degree of molasses exhaustion possible and the crystal concentration of the massecuite. A massecuite with a maximum crystal concentration will produce a final molasses of minimum purity, other things being

equal. If the crystal concentration is reduced below the maximum, final molasses purities will increase.

The reason for this is that the mother liquor is exposed to the greatest possible crystal surface area when the concentration of crystals is at its highest practical level.

To obtain this crystal concentration, a somewhat higher purity final massecuite must be used than has been generally the practice. The exact purity for any given optimum crystal concentration will vary, depending on the reducing sugar-ash ratio and Expected Purity. Also, the optimum crystal concentration itself may vary from factory to factory.

Based on the results of our factory tests at the Oahu Sugar Company, the writers have prepared a graph (located in the next section of this report) that shows the optimum massecuite purity calculated for different Expected Purities and for a 47 per cent yield of crystals on massecuite solids. Graphs that show the optimum purity for other crystal yields are also presented later. The fundamental requirement in approaching the determination of proper massecuite purity centers in the provision of sufficient crystallizable sucrose in the boiling material to produce the optimum final crystal concentration. The exact details involved in arriving at the figures shown on the graph are somewhat involved and will be explained fully later.

6. Seed Preparation

One requirement of the improved low-grade pan technique is that the grain nuclei be established by the seeding method. C and H Fondant & Icing sugar has proved quite satisfactory as seed for this purpose. In the tests conducted at the Oahu Sugar Company factory, it was found that 0.3 pound of Fondant sugar per 100 cubic feet of final massecuite would produce a final low-grade sugar with a grain size of about 0.25-0.30 mm

and a concentration of crystals equivalent to 47 per cent, by weight, on massecuite solids. This crystal concentration is equivalent to approximately 80 per cent apparent volume as determined by the shrinkage test.

A massecuite of this character, boiled so as to obtain reasonably uniform crystals, produces a relatively high purity low-grade sugar when purged with high speed centrifugals, as well as a lower final molasses purity than is normally obtained from factory massecuites.

In factory practice, the Fondant seed has been introduced into the graining charge in the form of a slurry and at a predetermined standard saturation.

This seed slurry is prepared for introduction by using the stipulated amount of Fondant seed sugar and mixing this seed with a relatively high purity saturated sugar liquor. The saturated liquor in which the Fondant seed is suspended merely comprises a vehicle that serves the primary purpose of dispersing the seed nuclei in the graining charge. It is very important that the mixing liquor be saturated before adding the Fondant seed, to insure that none of the seed is dissolved.

In recent tests, evaporator thick juice was saturated with raw sugar to produce the liquor in which the Fondant seed is suspended. This saturated liquor was prepared in a suitable container (about five gallons capacity), using a Lightning stirrer to assist in quickly building up the density to the saturation level. In the course of saturating the evaporator syrup its temperature was allowed to drop approximately 5° F. below the saturation temperature indicated by a specially prepared graph. After the solution was thus slightly supersaturated, the Fondant sugar seed was added and the slurry mix was then vigorously stirred with the Lightning

mixer for five to ten minutes in order to assure complete dispersion of all the fine seed nuclei.

Preparation of this seed slurry was timed so that it could be used some time within an hour after its preparation.

7. Seed Establishment

After a graining charge of standard volume and purity is drawn in the seed pan, steam is turned on the calandria and the charge concentrated to the saturation level established (by previous test) as optimum for introduction of the seed slurry. This saturation may be indicated by the boiling point elevation (read to an accuracy of about $\frac{1}{2}^{\circ}$ F.) at a standard vacuum or absolute boiling pressure. If the purity, volume and vacuum (or absolute pressure) are standardized and closely adhered to, the boiling point elevation which has been determined should hold good from strike to strike. However, any appreciable deviation in any one of these three factors will require selection of a different boiling point elevation.

As the selected boiling point elevation is approached, saturation of the graining charge is tested by drawing into the pan about two quarts of raw sugar and examining proof samples under a 50X microscope lens to determine if crystals are melting. If the graining charge is supersaturated, the surface of the crystals will be smooth and the edges sharp, and if it is undersaturated, they will be rough. Experience has indicated that about as soon as examination shows the crystal edges to be definitely sharp, the proper point for seed introduction has been reached. This point should correspond to the selected boiling point elevation.

As soon as the proper supersaturation for introducing the seed has been thus established, the previously prepared batch of Fondant seed is admitted at the bottom of the pan through a suitable

line provided for the purpose. In doing this, great care is exercised to avoid introduction of air, since the admittance of air with the Fondant seed will tend to shock in grain, and thus establish a larger number of seed crystals than desired.

8. Initial Grain Growth

After the seed crop has been established by introduction of the Fondant seed, the improved technique calls for slowing down the normal operation rate of the pan so that the supersaturation can be maintained well within the metastable zone during the critical growth period. In the case of calandria pans equipped with circulators, this is readily accomplished by periodically shutting off the steam supply to the calandria in accordance with a pre-established schedule. In the case of calandria pans equipped with steam agitation coils, the technique necessary to control supersaturation and at the same time maintain the minimum circulation requirements is more complicated. Very briefly, it involves:

- Operating the steam agitation coils.
- Throttling of the calandria steam supply.
- Gradual heating up of the massecuite.

All these are initiated as soon as pan proofs indicate that the seed crop has been fully established.

In a later section, the detailed patterns of pan manipulation, both for strikes boiled in circulator pans and strikes boiled in pans equipped with steam agitation coils, will be shown on a special chart.

9. Boiling Proper

The initial grain growth period is a very critical time in the boiling cycle and usually will extend over two to three hours after seed has been established. The end of this time and the beginning of the period termed "boiling proper" is determined approximately by the time

required to build up the apparent crystal concentration of the graining charge to a level of 50 to 65 per cent (by volume), as shown by the shrinkage test. By the time the crystal concentration has reached this point, the crystals have grown to a size of 0.12–0.15 mm and the fluidity of the mass has decreased approximately to the desired rather heavy boiling consistency. After this has been accomplished, the full boiling rate of the pan may be used and a small continuous feed started. The feed should be so adjusted during the remainder of the boiling period that the strike boils uniformly at a fairly heavy consistency. Irregularities in feed or feed densities which cause a strike to "free out" or which cause it to become too "tight" are apt to cause either false grain formation or development of conglomerates, or both.

In the course of the two months' experimentation with different pans, an important observation was made with respect to feed control as ordinarily carried out by the average pan man. This has to do with the rapid slowing down of boiling, which is natural in all calandrias after the static head approaches four to five feet. Strikes that are boiled to a level of five, six or seven feet above the calandria tube sheet, according to our observations, invariably have been "over fed." This is due to misjudgment of the rate of crystallization actually prevailing when the strike reaches the higher boiling levels.

As a general guide, the feed should be decreased at a rate approximately parallel to the decrease in evaporation rate in order to maintain the crystal concentration at the same level as established in the earlier stages of boiling. If this is not done, the strike is "freed out" and usually finishes with an objectionable surplus of mother liquor. In several cases it was actually observed that the pan men were merely diluting the massecuite with feed

material although they apparently believed the rising level in the pan to be a real growth in massecuite volume. Actually, very little crystallization occurred at the higher levels and the increased volume was principally due to the addition of the liquid feed.

Such conditions prevent the pan purity drops necessary for obtaining maximum exhaustion of final molasses and obviously should be avoided. Expressed in other terms, this means that the feed must be so regulated during the latter part of the boiling period as to end up with a "boiling down time" of $\frac{3}{4}$ -1½ hours and a massecuite with a crystal concentration that, by adequate trial, has been established as optimum for local conditions.

Reference to "boiling down" time, of course, applies to seed strikes which are boiled to final massecuite in a single

step. In the case of seed strikes that are cut into two or three footings, no "boiling down" time is necessary, but nevertheless freeing out of the massecuite by over feeding should be scrupulously avoided.

10. Use of Water During Boiling Period

It appears to be rather common practice for the pan man to use a small feed of water at different times during the boiling period to control supersaturation. If the procedures worked out in connection with this improved low-grade boiling technique are properly followed, this use of water is entirely unnecessary. It should be further stated that use of water is injurious to the quality of the grain crop and, therefore, highly objectionable. Water tends to melt out grain, particularly during the early stages of boiling. During the latter part of the strike its use tends to cause a grain crop of

Figure 1

PLAN I - SUGGESTED PATTERN OF PAN MANIPULATIONS FOR LOW-GRADE SEED STRIKES

For Pans Equipped with MECHANICAL CIRCULATORS
E.C.G. & W.K. - October, 1948

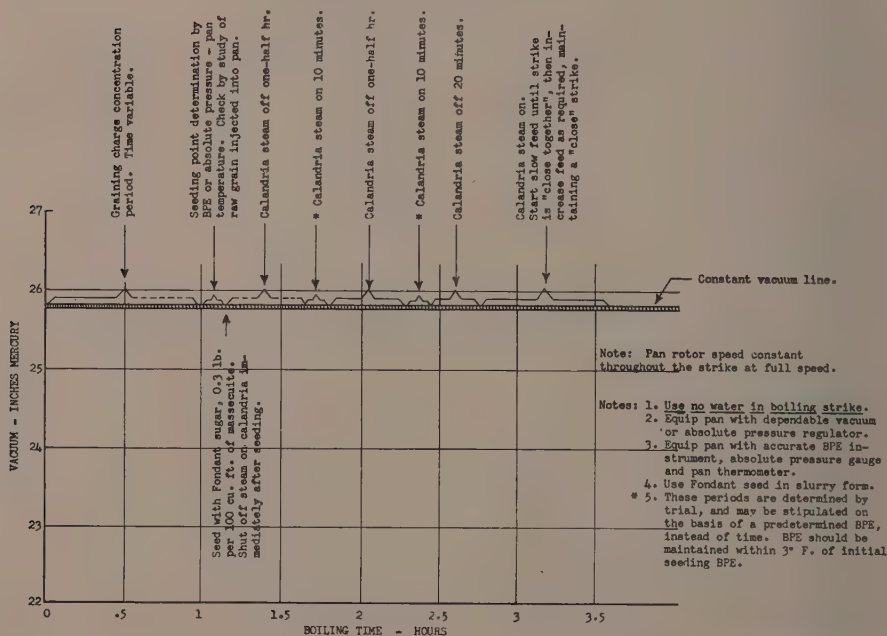
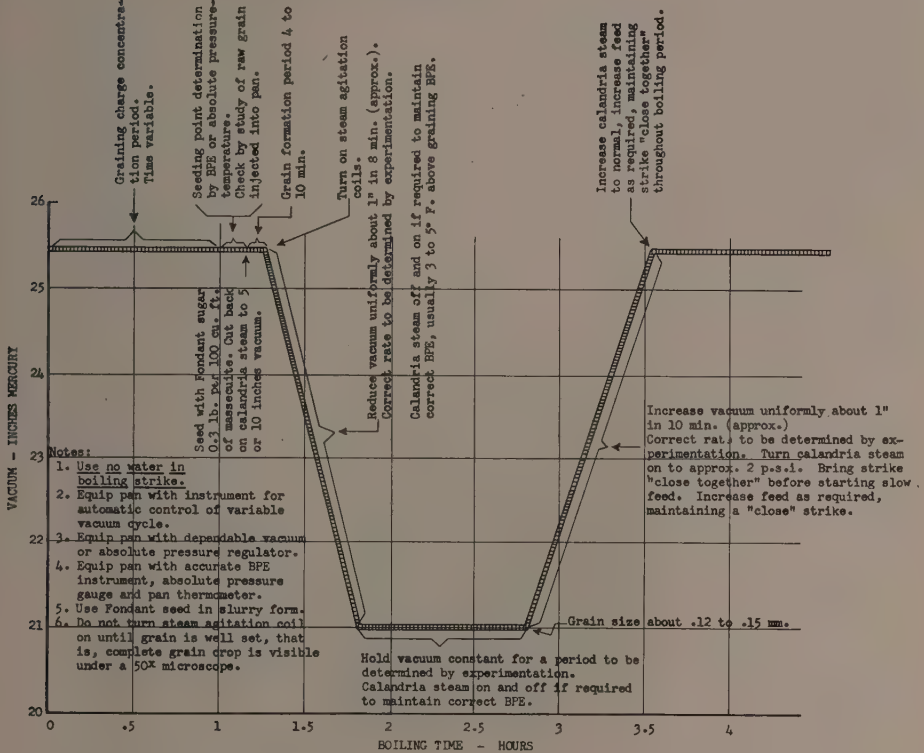


Figure 2

PLAN II - SUGGESTED PATTERN OF PAN MANIPULATIONS FOR LOW-GRADE SEED STRIKES

For Pans Equipped with STEAM AGITATION COILS
E.C.G. & W.K. - October, 1948



irregular size (due to partial melting of grain) and under certain conditions, encourages formation of conglomerates. If sufficient water is used it also may completely melt some grain during the latter stages of boiling when circulation is poor.

11. Patterns of Pan Manipulation for Seed Strike

As has been previously discussed, a suitable pattern of pan manipulation has been developed for boiling seed strikes in calandrias equipped with mechanical circulators. Also, because requirements are different when boiling a seed strike in a calandria equipped with steam agitation coils, a special pattern of pan mani-

pulation has been worked out to meet the somewhat different requirements imposed by this type of installation. The specific details of these two procedural patterns are shown in Figures 1 and 2.

12. Boiling Seed Footings to Final Strike

In the case of most of the experimental strikes it was found desirable to boil the seed strike and then cut this into two footings, from which were boiled two final masecutes. More recently, the Waipahu adaptation of this technique has developed a triple cut of the seed strike. When this is done, sufficient seed, of course, must be introduced into the seed strike to produce three final strikes.

In boiling the seed footings from the seed pan, the feed should be regulated so as to maintain the massecuite reasonably "stiff" during the boiling period. Proper regulation of the feed requires full recognition of the decreased boiling rate that ordinarily prevails as the massecuite level rises above the four to five foot stage. Under no conditions should the

massecuite be permitted to free out by "over feeding," and the "boiling down" time after the feed is shut off should be accomplished within a period of $\frac{3}{4}$ -1½ hours.

No other special requirements, except dependable vacuum regulation, are needed for production of a good quality final strike from a properly boiled seed footing.

RELATION OF MOLASSES EXHAUSTION TO CRYSTAL CONCENTRATION AND MASSECUIE PURITY

The primary objective of this improved technique is to produce a massecuite of superior quality in its response to conventional desugarization treatment in the factory pans, crystallizers and centrifugals. The specifications of such a massecuite have been designed so as to improve its potential for desugarizing the mother liquor (molasses). However, it should be emphasized that, to obtain maximum possible molasses exhaustion, not only must the massecuite be of best quality, but the time and equipment used in its production and treatment also must be adequate. The limitations imposed by insufficient and inadequate equipment cannot be eliminated as a basic influence on molasses exhaustion, irrespective of massecuite quality. However, when handling massecuites of highest possible quality, our results have shown that considerably better low-grade crystallization and molasses exhaustion work can be secured than is otherwise possible with the same basic equipment and operating rates.

The study of the data obtained from these experimental strikes indicated that certain definite relationships of importance exist between such factors as massecuite crystal concentration, crystal uniformity, crystal size and mother liquor density. These properties, to a great extent, control the quality of the massecuite.

While the number of tests possible during this limited preliminary experimental period was not sufficient to establish with much certainty the exact quantitative relationships between these factors, sufficient data have been obtained to permit some tentative conclusions.

The purpose of this section is to present such relationships as have been tentatively developed from analysis of the data secured.

MASSECUIE For purposes of this discussion, the crystal concentration of a massecuite may be defined as the percentage of total massecuite solids weight that is in crystalline form. In other words, it is the crystal (not final sugar) yield of the massecuite, expressed in percentage crystals on dry massecuite weight.

Because the crystals are grown in an impure solution they contain impurities and this must be considered when using the formula in calculation of crystal yield. Several tests have indicated that the purity of the low-grade crystal itself (without an adhering molasses film) is about 99%, and this figure has been used in subsequent calculations.

1. *Molasses Exhaustion Potential*

In this discussion, the Molasses Exhaustion Potential index of a low-grade massecuite is defined as the ratio of the

crystal surface area to the solids in solution. In making relative comparisons between different massecuites, this "Desugarizing Potential" may be calculated in several different ways. For instance, for purposes of comparison of massecuites produced under similar conditions (i.e., approximately the same average crystal size, massecuite temperature, and mother liquor supersaturation), this potential may be expressed as a ratio of the solid and fluid phases of the massecuites, using appropriate units. The simplest and most direct method is to determine the weight of crystals per unit weight of dissolved solids. In calculation, the following general formula may be used:

Ratio=

$$\frac{\% \text{ crystal yield per 100 parts of massecuite solids}}{\% \text{ dissolved solids per 100 parts of mass. solids}}$$

Expressed in symbols, this formula would be:

$$R = \frac{y}{100 - y},$$

where $y = \% \text{ crystal yield by weight on total massecuite solids}$

In making comparisons of the Molasses Exhaustion Potential of different massecuites that have different crystal concentrations, it is merely necessary to calculate the ratios as above indicated and then express the differences as percentages. The result gives the percentage increase or decrease in Molasses Exhaustion Potential, as used here. ("Desugarizing Potential" may be used synonymously with "Molasses Exhaustion Potential" for low-grade massecuites.)

The frequently overlooked concept upon which the Molasses Exhaustion Potential is based presumes that for any particular rate of sucrose deposition, the amount of sucrose deposited in a given time will be directly proportional to the

crystal surface available. For instance, if the surface exposed to a given amount of sugar bearing fluid is doubled, the capacity of the mixture to accept sugar from solution is also doubled, other things being equal.

This, of course, is theoretical. In practice, other factors alter the conditions in the case of low-grade massecuites, and, therefore, the actual results do not exactly correspond to the theoretical calculated results. However, analysis of test results indicates that the calculated change in Desugarizing Potential, arrived at as explained above, is a good criterion of the quality of the massecuite with respect to molasses exhaustion work. This relationship will be discussed in more detail in the next section.

Figure 3 shows the relationship between percentage crystal yield (concentration) on massecuite solids and percentage increase in Molasses Exhaustion Potential for the different crystal yields of a number of strikes boiled during the recent experimental period. The basis for comparison in these calculations was a massecuite of 38.6 per cent crystal yield, and the Molasses Exhaustion Potential is expressed in percentage increase from this base.

These results were obtained from the Oahu Sugar Company tests. The yield, or crystal concentration, of 38.6 per cent crystals that is used as a basis, represents the average results that existed before experiments started. In the course of test work it was found that the crystal concentration could be increased to approximately 47 per cent on weight of massecuite solids and this effected an increase in the Desugarizing or Molasses Exhaustion Potential of the massecuite, equivalent to approximately 40 per cent. To a large extent this increase is credited with the improvement in molasses exhaustion secured on the test strikes.

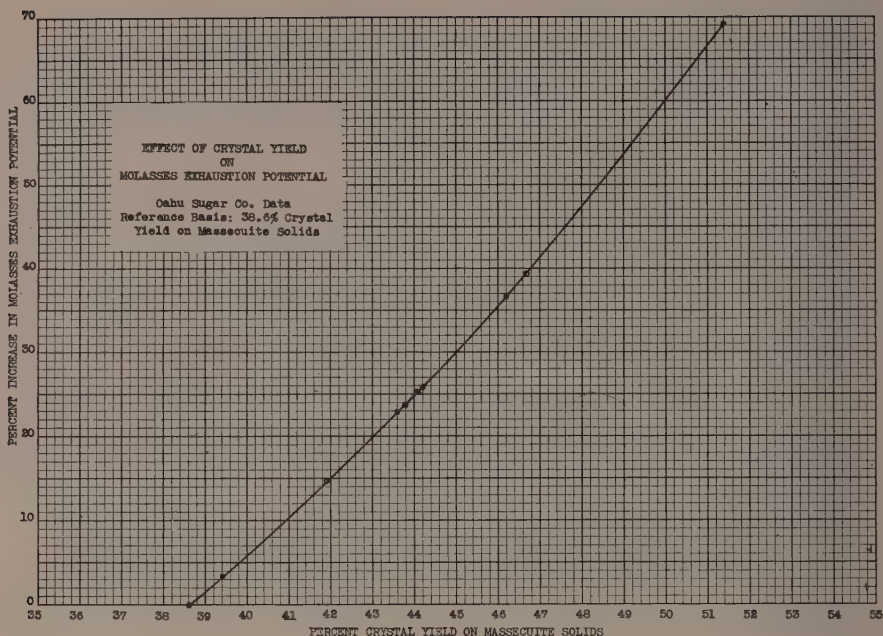


Figure 3

2. Method of Calculating Crystal Concentration or Percentage Crystal Yield

Some questions have arisen as to how the crystal concentration is determined and at this point it seems desirable to include the derivation of the formula used for calculation of percentage crystal yield, which in this discussion is synonymous with crystal concentration. A modification of the normally used SJM formula is necessary, since the result sought is to be expressed in percentage dry weight of crystal solids on massecuite total dry solids. The purities of the massecuite and of the mother liquor, or molasses are all that need to be known. In all cases the purity of the crystal is assumed to be 99°. The derivations have been worked out as follows:

Derivation of Formula for
Percentage Crystal Yield on
Massecuite Solids

Let y = Per cent crystal yield by weight
on massecuite solids.

S = Purity of sugar crystal.

J = Purity of massecuite.

M = Purity of molasses.

yl = Per cent sucrose yield in crystals,
on sucrose in massecuite.

Assume 100 = weight of massecuite solids
 y = weight of sugar crystals
obtained from 100 parts
massecuite solids.

$100 - y$ = weight of molasses solids
obtained from 100 parts
massecuite solids.

Method I—Sucrose balance

$$100J = Sy + (100 - y)M$$

$$100J = Sy + 100M - yM$$

$$100(J - M) = y(S - M)$$

$$y = \frac{100(J - M)}{S - M}$$

Method II—SJM formula for sucrose
recovery (HSPA Revised Methods
Book Chap. I, definition 55)

$$yl = \frac{S(J - M)}{J(S - M)} \times 100$$

$$\text{However } y = \frac{S_y}{J100} \times 100 = \frac{S_y}{J}$$

$$\text{Substitute } \frac{S_y}{J} = \frac{S}{J} \frac{(J-M)}{(S-M)} \times 100$$

$$y = \frac{100 (J-M)}{S-M}$$

3. Crystal Concentration—Molasses Exhaustion Relationships

As previously stated, the amount of data available from this preliminary experimental work are insufficient to establish exact quantitative relationships with surety. However, trends are sufficiently clear to lead us to believe that the relationships may prove to be about those indicated by the tables and graphs to follow.

Careful analysis of the data available has been made with the view to establishing, insofar as possible, the amount of molasses exhaustion improvement that may be expected from increasing the Desugarizing Potential of the massecuite by raising its crystal yield. The results are shown in Table 4. In the case of each crystal concentration level, the figures represent the average of a group of tests and hence should be reasonably reliable. All tests were made at the Oahu Sugar Company and were subjected to similar crystallizer curing treatment.

These results are not entirely consistent, probably because of some variation in other factors that also affect molasses exhaustion work. However, the cumula-

tive percentage improvement in molasses exhaustion follows reasonably close to the cumulative percentage increase in Molasses Exhaustion Potential brought about by the increase in crystal concentration.

A further analysis of results obtained at the Oahu Sugar Company has been made with the view of showing the quantitative relationship between desugarization and percentage crystal yield. Figure 4 expresses this relation in terms of crystal yield and "Points above Expected Purity." Figure 5 shows the influence of crystal yield on total points purity drop, which is another way of expressing the quantitative relation of increased desugarization per unit increase in crystal yield.

Both these curves have been developed for two different massecuite purities: $60.4 \pm 1.0^\circ$ and $58.5 \pm 1.2^\circ$. The curves are independent of crystallizer curing hours, due to the formula from which the data were calculated.

If the slopes of the curves in Figure 4 are substantially correct, which we believe them to be, it indicates that a change of 1 per cent in crystal yield may result in approximately 0.65° purity point increase or decrease in the final molasses purity.

The experimental results obtained at factories other than Oahu Sugar Company are insufficient in number to permit plotting of reliable curves for similar quantitative interpretations. However, the Molasses Exhaustion Potential per

Table 4

	(A)	(B)	(C)	(D)	(E)
	% Crystal Concentration	Ratio (A) (100-A)	% Increase in Mol. Exhst. Potential	Actual Points Above Exp. Pur.	% Reduction in Spread— Actual to Expected Mol. Pur.
Mass. AP					
58.1°	38.6	0.629	Basis	7.43	Basis
58.6	39.4	0.650	3.3	7.27	2.2
60.2	43.9	0.783	24.5	6.16	17.1
60.8	45.5	0.835	32.8	5.26	29.2
61.6	46.9	0.883	40.4	4.93	33.6

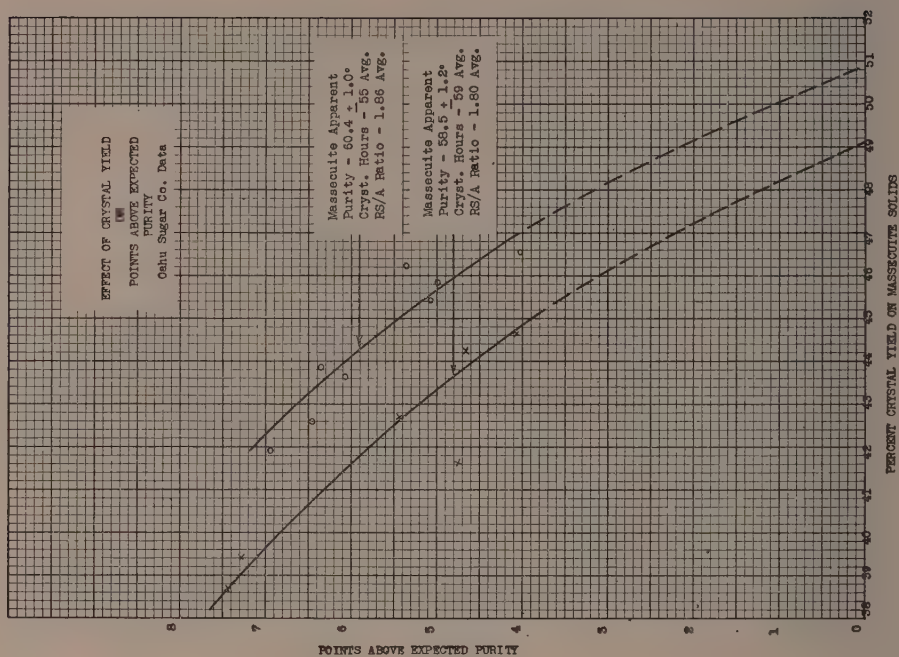


Figure 4.

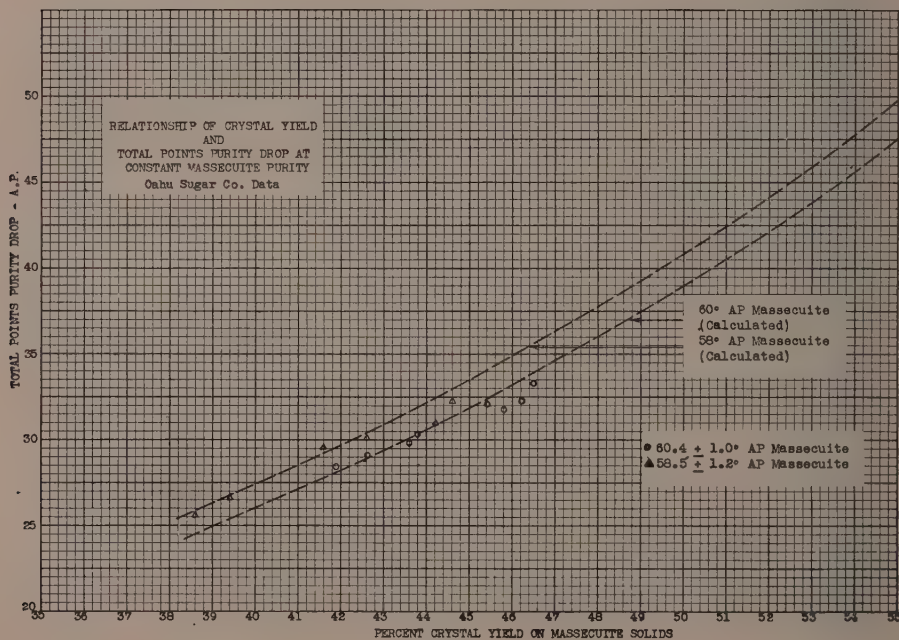


Figure 5.

point of crystal concentration increase may be calculated for these factories (based on the average results of the tests), by dividing the average purity drop accomplished (compared to Expected Purity) by the percentage points increase in crystal concentration. By using the figures from the preceding graphs for Oahu, together with the Ewa and the Waialua average results, an over-all figure may be obtained as shown in Table 5.

These data agree very well and appear to definitely establish the principle that molasses exhaustion may be increased by increasing the crystal concentration. It also supports the theory that the ratio of surface area to quantity of mother liquor is an effective element in enhancing the desugarization of low-grade boiling material.

The tentative indicated relationship between crystal concentration (AP basis) and molasses purities (suc./rds. basis) appears to be about 0.6° purity reduction for an increase of 1.0 per cent in crystal concentration within the ranges encountered.

This relationship has been determined from crystal yields calculated from massecuite apparent purities whereas the molasses values are sucrose-refractometer purities. A sounder approach may be made if both figures are placed on the same basis, apparent purities, for instance. Theoretical curves of this type have been plotted in Figure 5, and the

experimental points are shown to follow the theoretical curves very closely. From this graph, it is apparent that an increase of 1 per cent in crystal concentration (AP basis) results in a decrease in molasses purity (AP basis) of about 1.3°, in the ranges encountered. (This figure may also be obtained from the theoretical curves of Figure 14 which appears later in this section.)

4. Crystal Concentration Limitations

The foregoing statement, of course, is general and must be qualified because in factory practice there is a definite practical physical limit to the increase in crystal concentration that can be sustained.

It is well known that the presence of solid matter in a solution tends to reduce its fluidity. In the case of a mixture of sugar crystals and molasses, the crystals present in the mixture do not begin to have a strong influence on the fluidity of the massecuite, however, until the concentration approaches a certain critical point. Thereafter the fluidity decreases (massecuite becomes "stiffer") at a very rapid rate as the crystal concentration increases. These relationships were discussed in considerable detail (on pages 22 to 32) in E. C. Gillett's report "Low-Grade Sugar Crystallization" published May, 1948.

Another factor that affects the fluidity of the massecuite, of course, is the viscosity of the molasses, and the crystal concentration that can be tolerated in

Table 5
(A) (B)

Factory	% Points Crystal Conc. increase (% on Mass. Solids)	Reduction in Spread—Actual Exp't Purity (Suc./Rds. basis)	Mol. Purity Reduction per % Point Increase in Crystal Yield (B ÷ A)
Oahu.....	Value taken from Figure 4		0.65°
Waialua.....	5.0	3.27°	0.65
Ewa.....	5.5	3.48	0.63
Average.....		/	0.64°

different massecuites is governed to some extent by the differences in viscosity of the mother liquor. The viscosity of a low-grade sugar solution is determined by the natural characteristics of the non-sugars, and also by its density. These relationships are rather complex and their influence is not consistent, so it appears impractical to attempt standardization on one single figure that will be expected in all cases to exactly represent the optimum grain concentration. (Optimum grain concentration represents the maximum concentration consistent with the fluidity requirements for practical handling in the equipment.) Of course, the factor that primarily limits the grain concentration is the amount and character of the crystallizer and centrifugal equipment. These vary at different factories and, therefore, tend to establish different standards of acceptable low-grade massecuite fluidity. It is obvious, then, that in the course of selecting an optimum crystal concentration, all these variables must be reconciled. In practice, it probably will be found that each factory must select its own optimum concentration by trial reconciliation of all the influencing factors involved.

The results obtained during our experiments at Oahu Sugar Company have indicated that for the conditions prevailing at that factory, their optimum crystal concentration is approximately 47 per cent on massecuite solids (calculated on an AP basis). This figure very closely approximates that found best for the Crockett refinery and it is our general opinion from recent observations that many factories will find that their optimum concentration will fall between 45 to 48 per cent. Observations of factory performance at the Crockett refinery and a limited laboratory study of the influence of crystal concentration on massecuite fluidity indicate that the concen-

tration must reach approximately 43 per cent before the crystals begin to materially reduce the massecuite fluidity. While this threshold figure may vary with different viscosity mother liquors, the extent of its variation may not prove to be a major deterrent to selection of a relatively high crystal concentration under normal factory working conditions. It is believed, therefore, that crystal concentration of at least 43 per cent should represent a reasonably safe minimum and that in most cases a somewhat higher concentration (45 to 48 per cent) probably can be tolerated.

When raising the concentration of crystals in the massecuite, it is suggested that it be done in successive steps until the optimum is approached. If this point is exceeded, higher purities will result; also the low-grade station will be called upon to handle an unnecessarily heavy load of massecuite.

5. Selection and Control of Crystal Concentration

Since the crystal concentration is in essence the yield of true crystals that is obtained from the final massecuite, it is quantitatively controlled by the final molasses purity and the massecuite purity. Actually, sufficient sucrose must be provided in the boiling material to permit growth of a final crystal crop of the established optimum concentration. Therefore, an important requirement is that massecuite purity must be sufficiently high to permit crystallizing the amount of sugar required to produce the desired crystal concentration. In estimating the amount of sucrose available in a given purity boiling material, consideration of the prevailing Expected Purity of the molasses also must be taken into consideration.

It has been well established by Experiment Station work that the Expected

Purity of molasses changes with the reducing sugar-ash ratio. With high ash ratios more sugar can be crystallized out of the molasses whereas with low reducing sugar-ash ratios less sugar can be recovered from the molasses, when subjected to the extensive exhaustion methods used to determine Expected Purity. Therefore, such differences in recoverability of sugar from different molasses will influence the purity of the massecuite to be used. For instance, if the crystal yield is maintained at a constant level and the Expected Purity is low, more sugar is recovered from the molasses and, therefore, less has to be initially provided; hence, under such conditions, the massecuite purity should be lower than would be the case with a high Expected Purity. On the other hand, if less sugar is recoverable from the molasses a higher massecuite purity will be required to provide the same crystal yield.

By use of the SJM formula and by selecting any specific minimum purity, it is possible to calculate with a satisfactory degree of accuracy the massecuite purity that will give the desired crystal concentration with a boiling material of any particular reducing sugar-ash ratio.

It is generally recognized that the Expected Purity is a figure that represents the probable maximum exhaustion of molasses at 600 poises viscosity, as determined in the laboratory. In actual factory practice, we do not normally expect final molasses of this viscosity to be exhausted to this extent. The difference between factory work and laboratory maximum exhaustion, as indicated by Expected Purity, averaged approximately 7.45° for the 1947 crop. Of course, the objective of a factory may be set at any particular point, either at or above Expected Purity. If, for instance, an "Objective" Suc./rds Purity of three points above Expected Purity is selected

as a basis, the apparent purity of the massecuite can be readily established by the following approach:

- Determine the reducing sugar-ash ratio by laboratory analysis and then select the corresponding Expected Suc./rds Purity from the HSPA Experiment Station tables.
- By comparing analyses of apparent purities and Suc./rds purities, determine the current spread between Suc./rds purity and apparent purity of molasses.
- If the objective is to be set at three points above Expected Purity, add three points to the Expected Purity and subtract from that figure the factory difference factor between actual Suc./rds purity and apparent purity. The result is a figure which is on the apparent purity basis and may be used in calculating the massecuite purity that should give the refractometer sucrose purity of molasses three points above Expected Purity, for any given crystal yield.
- Inasmuch as all factory working figures are based on apparent purity, the apparent purity of the massecuite may be readily calculated by the SJM formula, using the objective molasses apparent purity and the local optimum crystal yield.

Development of a table or graph to indicate the proper massecuite purity necessary to meet the various requirements for best molasses exhaustion work appears both practical and warranted as a means of crystal concentration control at the factory. With this in view, graphs that may be used for the purpose have been drawn up for a limited number of crystal concentrations. The calculations and table of data for Figure 6 are shown in Table 6. Similar data for Figures 7 and 8 may be found in the appendix.

Basis: 47% crystal yield on massecuite solids.

Crystal AP=99.0°

$$y = \frac{J - M}{S - M} \times 100$$

(NOTE: This formula is the SJM derivation previously developed for calculation of crystal yield as a percentage on massecuite solids.)

Since it is desired to know what massecuite purity will give a 47 per cent crystal yield of 99° AP, these values may be substituted in the above formula and the formula solved for J.

$$47 = \frac{J - M}{99 - M} \times 100$$

$$J = 0.53M + 46.53$$

Obviously, it is necessary to know M (or molasses purity) before the massecuite purity J can be determined.

As pointed out above, M is considered as an Objective Expected Purity which parallels Expected Purity but which

would generally be on a somewhat higher level since usually it will *not* be possible to attain complete exhaustion with available factory equipment. M is expressed as an apparent purity and is determined as follows:

Let A = Difference existing between refractometer-sucrose purity and apparent purity of molasses for the particular factory.

EP = Expected Purity

D = Difference between assumed Objective Expected Purity and Expected Purity for the factory.

Then,

Objective Expected Purity (refractometer sucrose purity basis)

$$= EP + D,$$

and,

Objective Expected Purity (apparent purity basis)

$$= M = (EP + D) - A.$$

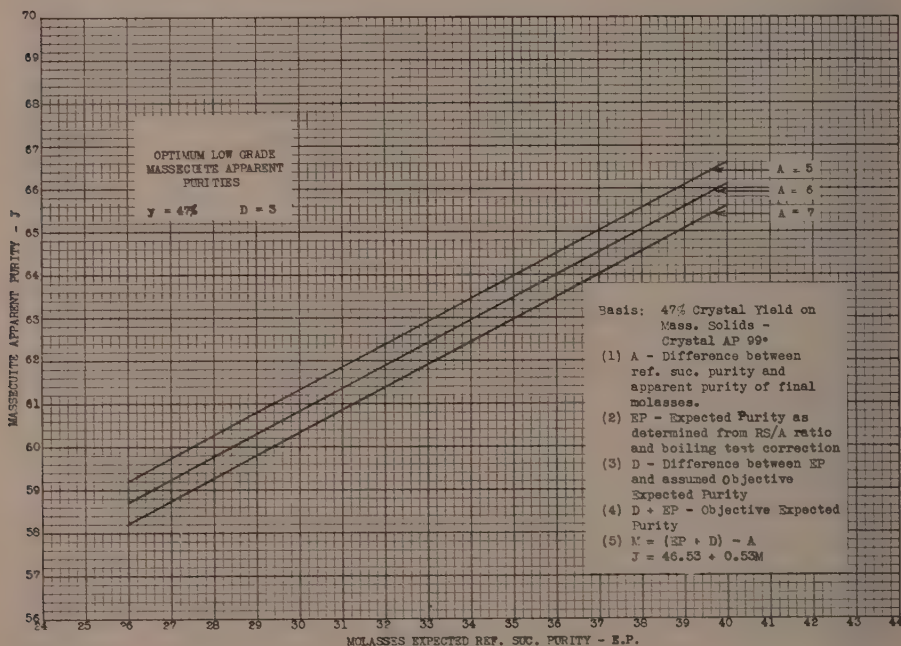


Figure 6.

Table 6
Data Calculated for Ref. Suc. Purity—
Apparent Purity Differences of 5, 6, and 7 for Figure 6
($y = 47\%$, $D = 3$)

Expected Sucrose Purity	Objective Expected Sucrose Purity	Calculated Mass. AP		
		A=5	A=6	A=7
24°	27°	58.19°	57.66°	57.13°
25	28	58.72	58.19	57.66
26	29	59.25	58.72	58.19
27	30	59.78	59.25	58.72
28	31	60.31	59.78	59.25
29	32	60.84	60.31	59.78
30	33	61.37	60.84	60.31
31	34	61.90	61.37	60.84
32	35	62.43	61.90	61.37
33	36	62.96	62.43	61.90
34	37	63.49	62.96	62.43
35	38	64.02	63.49	62.96

It seems reasonable to base the calculation of massecuite apparent purity on the assumption that the optimum crystal concentration will be attained when the molasses purity is reduced to the objective Expected Purity instead of the true Expected Purity. The latter, of course, is the ideal objective and, if the factory is operating on a reduced schedule so that ample time and equipment are available to attain Expected Purity, such a basis probably should be adopted for the massecuite purity calculation. On the other hand, if such a purity level of massecuite is used and Expected Purity is not substantially reached, a definite penalty is imposed, by virtue of the fact that the crystal concentration, and, hence, crystallization potential, will fall below optimum. Under such conditions an Objective Expected Purity should be used instead of the actual Expected Purity in the massecuite purity calculation if the most effective molasses exhaustion is to be attained with existing equipment and available time.

The improved technique proposed (which, among other things, requires raising of low-grade massecuite purities in most instances) will effect a certain degree of improvement in molasses exhaustion. However, in order to con-

sistently secure molasses at the Expected Purity level in regular factory practice, it is not unreasonable to expect that the factory massecuite will require a boiling and curing treatment equally as effective as that used in the laboratory for determination of Expected Purity. Such an exhaustive treatment would mean considerably longer curing time; hence more equipment, probably of a more rugged nature, would be required. This might not be economically practical. Hence, selection of a lesser objective (say two to three points above Expected Purity) might be more practical in most cases—particularly to start with.

An actual example of how equipment affects results, when massecuite purities are lower than optimum, may be of interest.

During one of the test periods (several weeks) at Oahu Sugar Company, the regular factory low-grade massecuite averaged 58.6°, and with this purity a crystal yield of 39.4 per cent was obtained. The factory molasses produced averaged 7.27 points above the Expected Purity figure.

Now with the same massecuite purity the crystal concentration would have been raised to 45.2 per cent if the factory treatment had been adequate to

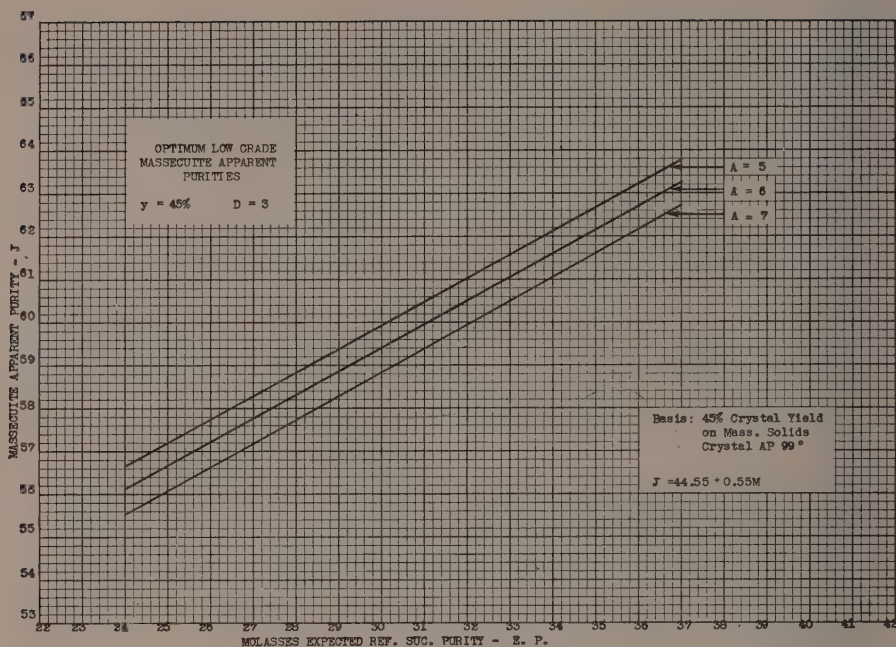


Figure 7.—See legend in Figure 6.

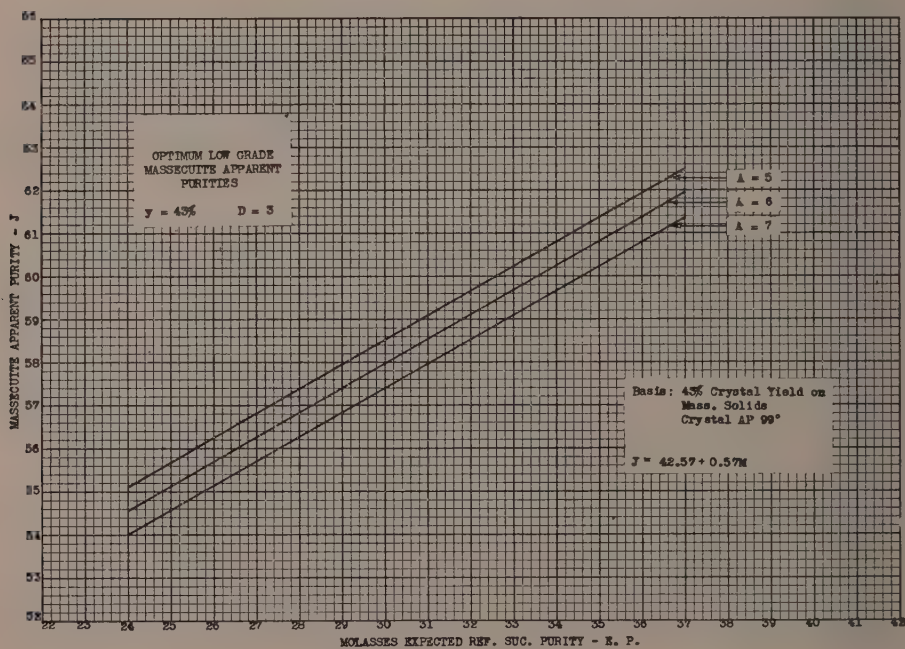


Figure 8.—See legend in Figure 6.

force out of solution all the crystallizable sugar from the molasses—so as to reach Expected Purity level. However, this condition did not prevail, and the problem was, therefore, approached from the direction of increasing crystal concentration and Desugarizing Potential by means of an increase in massecuite purity—as next explained. During the same period, a higher average massecuite purity level, 60.8° AP, was used for experimental strikes, with the result that an average crystal yield of 45.5 per cent was secured, and the spread between actual and Expected Purity was reduced 2.0° below the average for the regular strikes—principally because of the greater crystallizing potential of the massecuite thus obtained.

Now the reason why the regular results did not produce a 45.2 per cent yield was primarily because the time and

equipment were inadequate to permit such a degree of molasses exhaustion. Actually, the sugar was available, and would have produced a crystal concentration of 45 per cent if it had been possible to exhaust the molasses to its Expected Purity under prevailing conditions.

In such a situation a penalty is imposed by “shooting” at an objective molasses purity that is unattainable with the available time and equipment and it is our feeling that greater financial returns will be obtained if the basis for figuring massecuite purities fully takes into consideration the practical limitations of molasses exhaustion that exist at each factory.

However, it might be of interest to inspect the massecuite purity levels that result when it is assumed Expected Purities will be actually and regularly secured in factory practice. Figures 9, 10, and 11

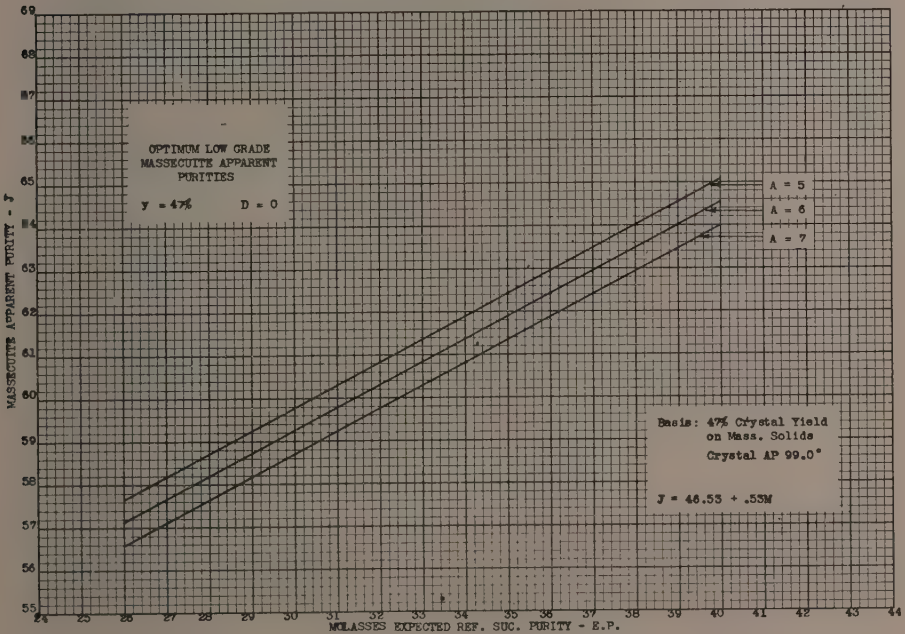


Figure 9.—See legend in Figure 6.

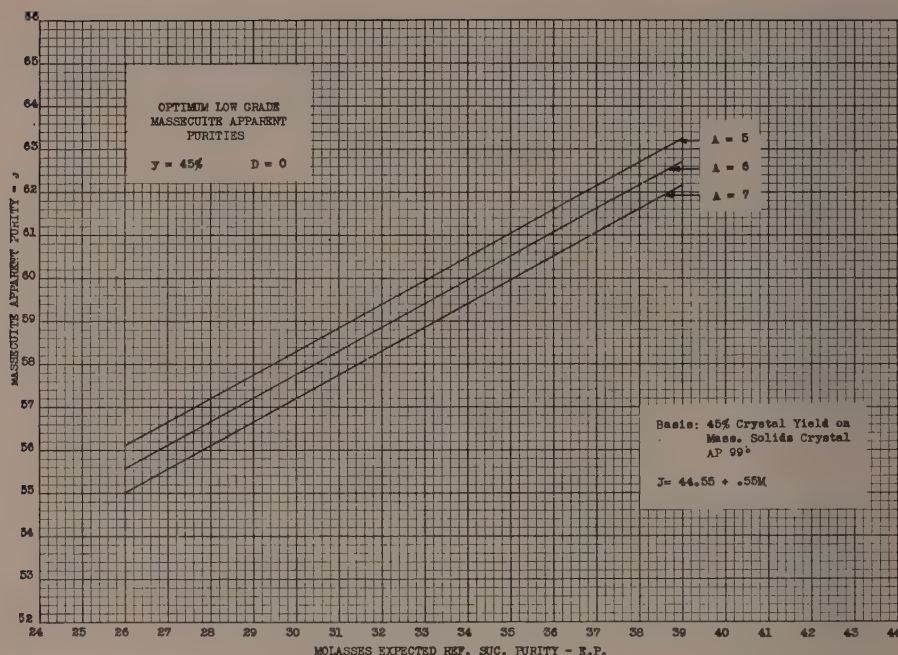


Figure 10.—See legend in Figure 6.

show the calculated massecuite purities on the basis of complete molasses exhaustion (Expected Purity attainment) and optimum crystal concentration of 47, 45 and 43 per cent, respectively.

6. Economic Importance of Maintaining Optimum Crystal Concentration

The graphs shown in Figures 6–11 are suggested for compensating for the influence of variations in Expected Purity brought about by changes in reducing sugar-ash ratio. The massecuite purities are calculated from practical figures and presuppose that the crystal concentration secured is exactly as indicated for the various basic conditions represented by the different graphs. In actual practice such perfection of control is not attainable and should not be expected. However, it is extremely important from the economic standpoint to install effective control measures that will prevent

substantial deviations from the optimum crystal concentration level.

In factory practice, crystal content of a massecuite may be lower than the established optimum figure even though the massecuite purity is correct. The lower yield may be a result of having insufficient seed due to inaccurate seed establishment, or it may be brought about because pan manipulations (such as the use of water) dissolve some of the initial seed. It may also come about as a result of the strike not being “boiled down” to a sufficiently high density. Other reasons, such as the effect of slow boiling material and “over feeding” the massecuite might also contribute to a drop in crystal concentration below the optimum level, unless such factors are compensated for by longer boiling times. All these factors arise from conditions of boiling and curing and may occur even though massecuite purities are properly

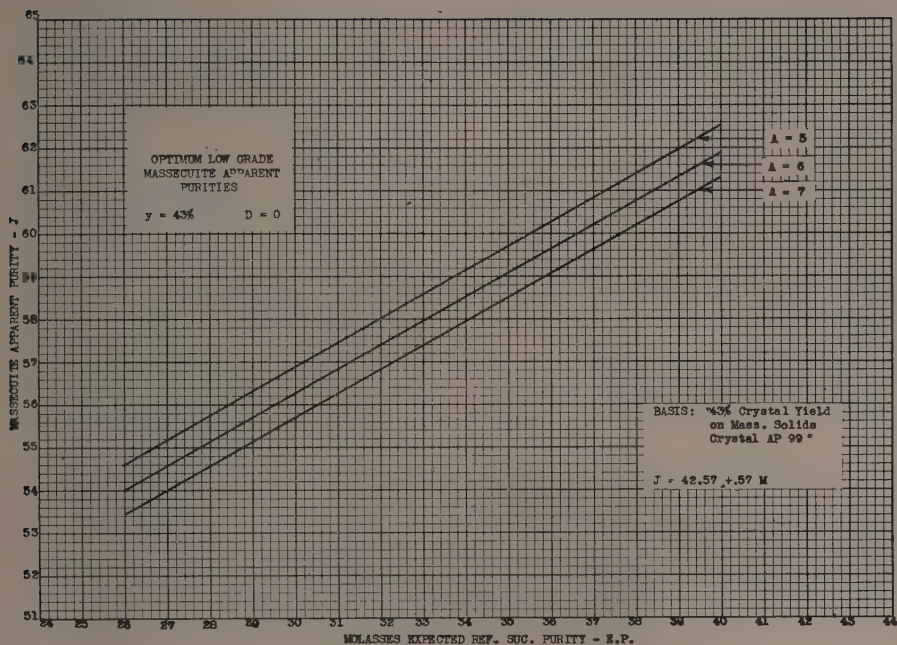


Figure 11.—See legend in Figure 6.

set for production of the optimum yield under normal conditions.

The importance of avoiding pan and crystallizer irregularities that result in deviation in crystal concentration and the value of selecting the proper massecoite purity to give optimum crystal concentration cannot be overemphasized. For instance, the need for good pan work is evidenced by the fact that best molasses exhaustion results are secured with maximum pan purity drops. Also, lower molasses purities are secured with longer crystallizer curing times, other things being equal. Furthermore, the importance of the maximum possible, or optimum, crystal concentration is considerably greater with shorter crystallizer curing times. Figures 12 and 13, which are based on data obtained during the experimental period, indicate the importance of these relationships.

Another factor that deserves con-

siderable attention when viewed from the economic standpoint is an effective and accurate control over factory massecoite purity. The effect of deviations from the established optimum massecoite purity line can be resolved directly into dollars and cents loss. A loss is involved irrespective of the direction of the deviation, although the magnitude is different in the upward direction than in the downward direction. To emphasize the importance of this control, the following calculation may be helpful. In passing, it may also be well to mention that if the established optimum figure itself is in error, the same general penalty will be imposed, as in the case of uncontrolled deviations.

● Deviation Above Established Optimum

Assume:

Optimum crystal yield is 47%

Expected Purity (EP)	28°
Objective Expected Purity— 3° above EP	31°
Suc./ref. pur—AP = (A)	6°

Then:

The proper massecuite purity may be calculated by formula as follows:

Objective Expected Purity

$$28 + 3 = 31^\circ$$

Objective Apparent Purity

$$31 - 6 = 25^\circ = M$$

$$47 = \frac{J - 25}{99 - 25} \times 100$$

$$J = 59.8^\circ$$

Now assume massecuite purity is permitted to increase sufficiently to increase the crystal concentration to 48 per cent. If 47 per cent is the maximum and optimum crystal concentration, then the massecuite would be too "stiff" to handle in local equipment. To remedy this

situation either the crystallizer would be watered to reduce the massecuite "stiffness," or the strike would not be boiled beyond the 47 per cent crystal yield limitation. In either case the final crystal concentration would have to be 47 per cent (because of physical limitations of "stiffness"), although sufficient sucrose would be available to grow a crystal crop of 48 per cent concentration.

Under such a situation the molasses purity would increase, as shown by the following calculation:

Massécuite Purity required for 48 per cent crystal and the same 25° AP molasses basis used in the previous calculation.

$$48 = \frac{J - 25}{99 - 25} \times 100$$

$$J = 60.5^\circ$$

But if the crystal yield is reduced to 47 per cent (optimum limit), with this

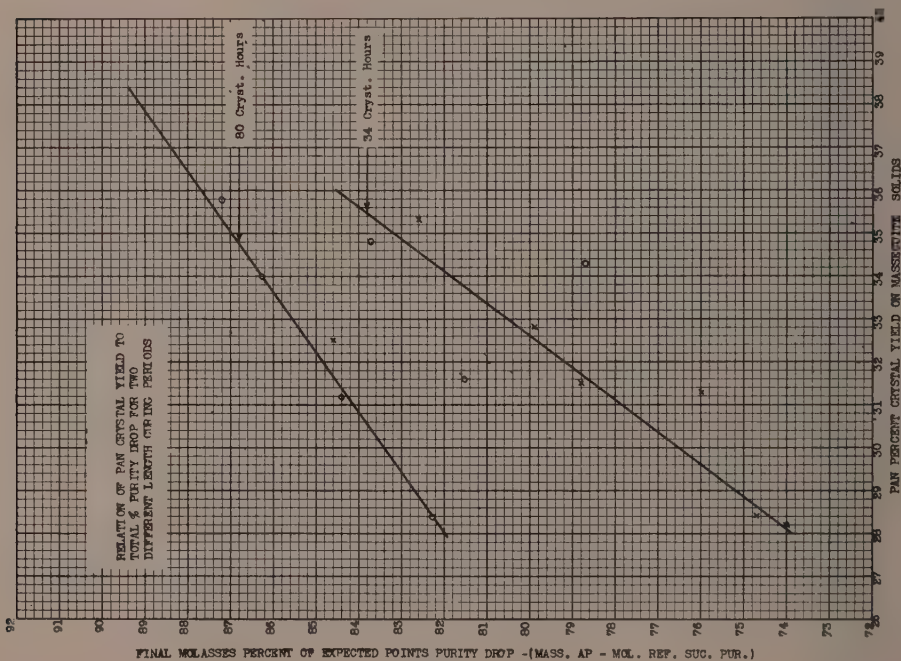


Figure 12.

purity massecuite (60.5°) the molasses purity would be

$$47 = \frac{60.5 - M}{99 - M} \times 100$$

$$M = 26.4^\circ$$

Therefore:

With a massecuite purity increase of $60.5^\circ - 59.8^\circ = 0.7^\circ$ above optimum, the crystal concentration would be increased 1 per cent point above optimum, and if this condition is corrected by water addition to the crystallizer or by boiling to a lower density massecuite, the molasses purity would increase

$$26.4 - 25.0 = 1.4 \text{ purity points.}$$

At 60 cents a point per ton of raw this would mean a calculated financial loss of

$$1.4 \times 60\text{¢} = 84\text{¢ per ton of raw sugar}$$

● Deviation Below Established Optimum

From the data in Table 5 the loss in molasses desugarization tentatively established by actual experiment is equivalent to about 0.6° purity points for *one* point (per cent) drop in crystal yield with purities on the customary factory bases. This represents a possible loss in molasses exhaustion, equivalent to about—

$$0.6^\circ \times 60\text{¢} = 36\text{¢ per ton of raws.}$$

On the other hand, if purities are all expressed on an apparent basis, it has been shown that the molasses purity would increase about 1.3° for a 1 per cent drop in crystal concentration. This is roughly equivalent to the purity drop of 1.4° calculated above for an increase of 1 per cent in crystal yield, and is equivalent to:

$$1.3 \times 60\text{¢} = 78\text{¢ per ton of raws.}$$

This higher figure (78 cents per ton)

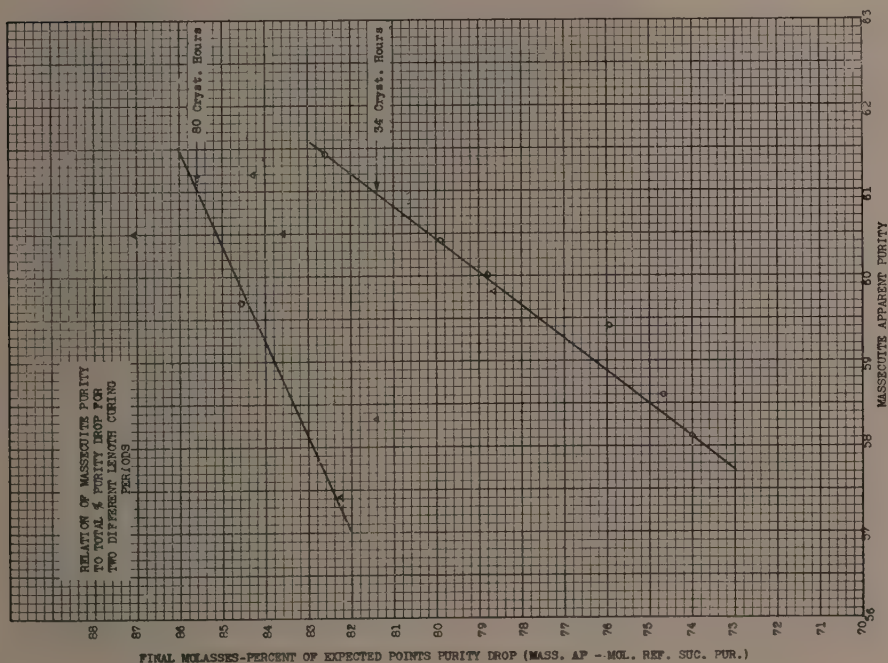


Figure 13.

would appear to more nearly represent the financial loss from a 1 per cent decrease in crystal yield.

A calculation similar to that made under "Deviation Above Expected Optimum" will show that a drop in massecuite purity of 0.8° would cause a decrease of 1 per cent in crystal yield.

● **Recapitulation of Financial Penalty for Deviation from Optimum Crystal Concentration**

	Possible loss per ton raws
Mass. purity .7° above optimum—	84¢
Mass. purity .8° below optimum—	78¢

These calculations indicate the value of a very close control over low-grade massecuite purity.

Figure 14 shows the calculated relationship of crystal yield to final massecuite purities—at constant purity level lines. Inspection of this graph will confirm the importance of high yields and the penalty in molasses purities resulting from a drop below the level of any particularly established yield at a constant massecuite purity.

For illustration, two points are shown on the 60° massecuite purity line indicative of a change in percentage crystal yield of 2 per cent (i.e., 47 to 45 per cent). This change in percentage crystal yield results in an increase of 2.6° (i.e., 25.5° to 28.1° AP) in molasses purity. An increase in molasses purity of this magnitude could occur if it were necessary to resort to operating practices resulting in the melting of grain in the crystallizer or centrifugal.

7. Summary of Changes in Internal Relationships During the Massecuite Curing Period

During the massecuite curing period a number of changes in the internal rela-

tionship of the various massecuite properties take place. For instance, mother liquor purity and density will drop as curing proceeds, and, at the same time, the percentage crystal concentration will increase because of the transfer of sucrose from the liquid to the solid phase. Also the crystal size will increase and the shrinkage factor will decrease during the curing period as the result of these other internal changes.

It may be of interest to scrutinize Table 7, which shows the calculated changes of the various massecuite properties that develop during curing. The initial data used for these calculations represent averages from the group of 10 special test strikes boiled at Oahu Sugar Company. Other changing conditions were calculated from these initial data. The details of the calculations involved will be found in the Appendix.

CRYSTAL UNI- The amount of
FORMITY, SIZE data available
AND MOTHER from these pre-
LIQUOR DENSITY liminary test
strikes is insufficient to permit the development of quantitative relationships of these various factors. However, a few comments relating to our general observations on their influence may be of interest.

1. Uniformity of Crystal Size

With the proposed boiling technique it has proved consistently possible to produce a crop of substantially uniform size crystals. This property of the massecuite has resulted in the production of a considerably higher purity sugar and has offered the possibilities of increasing the low-grade station centrifugal capacity.

A higher purity sugar, of course, reduces the circulating load of non-sugars throughout the entire pan house. However, the uniform grain offers other possibilities, such as the production of higher

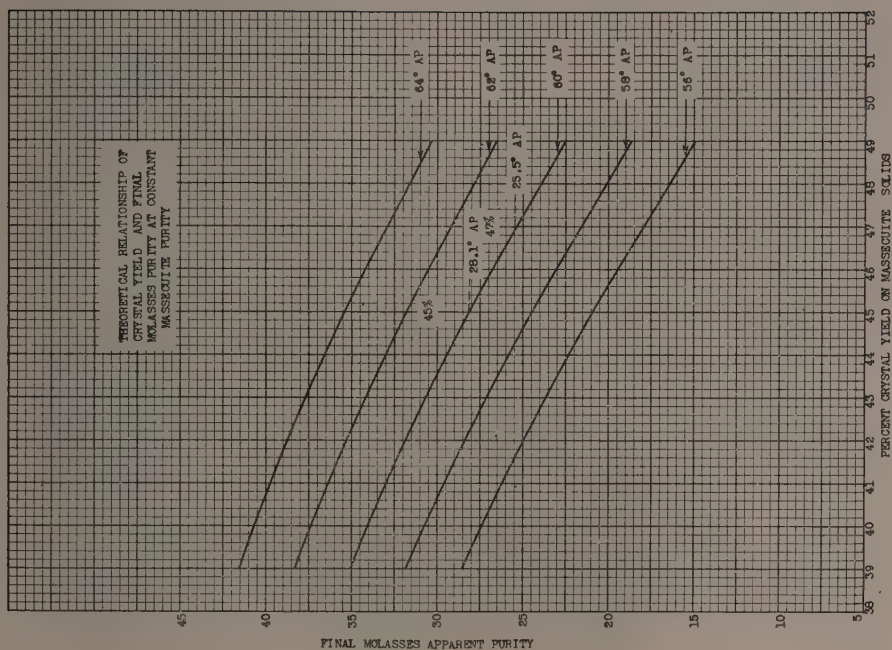


Figure 14.

density massecuites which should give better desugarization; also, the possibility of reducing crystal size exists. The latter in particular is important because the aggregate crystal area of the massecuite may be materially increased by a nominal reduction in crystal size, thus increasing the Molasses Exhaustion Potential and thereby further reducing molasses purity. Similar end benefits are offered by increasing the mother liquor density, as the resulting higher supersaturation tends to more completely desugarize the molasses.

2. Possible Benefits from Change in Average Crystal Size

The grain size is important from two opposing standpoints.

- **Large Size Crystals.** As the size of the crystal increases, the pore space between the crystals also increases in

size, and consequently, molasses drainage in the centrifugals is more readily accomplished. This, together with the fact that larger size crystals have a smaller aggregate crystal surface area, results in higher purity low-grade sugars—provided, of course, the crystals are reasonably uniform in size.

The primary improvements resulting in factory work from the larger size crystals is a potential increase in low-grade centrifugal station capacity and a greater pan (both low-grade and raw) and crystallizer net capacity, due to the reduction in molasses circulating load which results from higher purity sugar.

In the case of Oahu sugar tests, with reasonably uniform crystal size averaging 0.27–0.30 mm, it was possible to reduce centrifugal drying time by approximately $\frac{1}{2}$ and still secure a

low-grade sugar that was as high in purity as that normally produced. The importance of maintaining the low-grade crystal size at the higher end of the practical range, of course, is determined by local needs and benefits that might be derived.

● **Smaller Low-Grade Crystals.** A possibility exists, with good uniform crystals, to increase the Molasses Exhaustion Potential by reducing the size of the crystals. This, of course, is brought about by the fact that the area of the crystals per unit weight materially increases with a reduction in size. However, there is a limit to the minimum size of low-grade crystals, and this limit is established primarily by the ability of the low-grade centrifugals station to "dry" the sugar and produce a satisfactory purity. This limit, obviously, will depend largely upon the local equipment available and its characteristics.

It may be calculated that a decrease in the crystal concentration of a massecuite of 1 per cent represents a reduction of 2.3 square feet in crystal area per pound of dissolved solids. A reduction of 1 per cent

in crystal concentration has been estimated in the previous section, to be equivalent in value to 78 cents per ton raw sugar, based on performances secured in those preliminary experiments. Since a change of 0.014 mm in crystal size within the general range under discussion (approximately 0.3 mm) may be shown to be equivalent to 2.3 square feet, the value of such a decrease in size then would also be equivalent to 78 cents. Details of this calculation may be found in the Appendix.

These relationships are brought out to indicate that even a small change in crystal crop average size may be translated into definite financial terms and that the size of the values involved is deserving of consideration. This merely emphasizes again the necessity for precise control over boiling conditions and the use of a technique and procedure which will assure dependable and reproducible results.

3. Mother Liquor Density

Considerable work has been done by the Experiment Station HSPA which has proved that lower purities and better molasses exhaustion may be secured when the massecuite is boiled to a density range that produces final molasses

Table 7
Relationships in a Low-Grade Massecuite
Summary

	Massecuite Leaving Pan	Massecuite Leaving Crystallizer	Massecuite Leaving Crystallizer After Additional 2° Purity Drop
Massecuite Purity (AP).....	61.6°*	61.6°*	61.6°*
Purity Drop (AP).....	19.9°*	33.0°*	35.0°
Mother Liquor Purity (AP).....	41.7°	28.6°	26.6°
Mother Liquor Density.....	92.0* RDS	90.35 RDS	90.12 RDS
Crystal Yield—% on Massecuite Solids.....	34.8	46.9	48.3
Calculated Shrinkage—%.....	40.2	19.2	16.7
Measured Shrinkage—%.....	(41.9†)	20.0*	(17.4†)
Length of Crystal—mm.....	0.27*	0.30	0.30
Points Above Expected Purity (Suc./RDS Basis).....	17.0	4.93*	3.1

* Initial Data—Actual results—Average of 10 experimental strikes boiled at Oahu Sugar Company.

† Calculated on Basis of measured 20% shrinkage leaving crystallizer.

NOTE: Detailed calculations are shown in Section 3 of the Appendix.

of the highest practicable viscosity. With the present quality of low-grade seed and existing centrifugal equipment, it is normally the practice to boil the mother liquor to a density that will result in about 600 poises viscosity molasses at a saturation temperature of 50° C. With a crop of uniform crystals of present size or a crop of larger size uniform crystals an increase in the density and viscosity of the final molasses probably could be tolerated at the centrifugal station. In such an event, better molasses exhaustion should be obtained in accordance with results established by Experiment Station work.

In our tests, time and available manpower did not permit the exploration of these possibilities. However, it is believed that the potential improvement that might be secured by heavier pan boiling is sufficiently attractive to merit some study in subsequent test work.

SUMMARY AND CONCLUSIONS Several important points that have been tentatively established by this investigation and discussed in this section are summarized as follows:

- Lower molasses purities have been obtained by *raising massecuite purities*.
- Higher massecuite purities are needed if the crystal concentration is substantially below the optimum level so as to provide enough crystallizable sugar in the boiling material to obtain the optimum crystal concentration.
- That increased crystal concentration does not seriously decrease fluidity until it approaches 43 per cent by weight on solids, seems generally true. An optimum crystal concentration for one factory has been established at 47 per cent crystals on massecuite solids, and a range between 45–48 per cent seems reasonable for most factories.

- By increasing the crystal concentration to the limit, the maximum Molasses Exhaustion Potential is secured, since the mother liquor is thus exposed to the maximum crystal surface and hence, the greatest possible desugarizing action.
- The average crystal size of the massecuite affects the aggregate crystal surface area available for desugarization. Thus, with a good quality crop of reasonably uniform crystals, such as is obtainable with the improved technique, it may be possible to reduce crystal size and thereby increase the massecuite Desugarizing Potential and hence, decrease the molasses purity.
- Also, with a crop of reasonably uniform crystals, better drainage of molasses is secured at the centrifugals. This presents an opportunity to raise molasses densities, viscosities and supersaturations—thereby also effecting a reduction in final molasses purity.
- Too much emphasis cannot be placed on the importance of establishing the exact optimum crystal concentration for each factory by local tests and then maintaining this concentration within very close limits in factory practice. The necessity for this close control is evident when it is realized that a heavy penalty is paid for even a ± 1 per cent deviation from the optimum crystal concentration. A deviation of this amount above the optimum concentration may cause molasses purities to rise as much as 1.4° while a deviation of 1 per cent below the optimum may cause the molasses purity to rise about 1.3°. These increases in purity are equivalent to 84 and 78 cents per ton of raw sugar, respectively.

While further experiments and analyses are required to establish with quantitative exactitude the various relationships discussed in this section, there appears to be sufficient evidence from studies already made to warrant certain tentative conclusions. Such relationships as have been presented are, of course, largely on a relative basis, but, nevertheless, should serve as a guide in initiating improvement in low-grade sugar boiling

methods. Tests at a greater number of factories than was possible during this experimental period should disclose further qualitative relationships between massecuite quality and molasses exhaustion and will serve to more definitely establish a guide pattern for low-grade pan house work. Exploration along such lines should produce worth-while financial returns through more complete molasses exhaustion.

GENERAL COMMENTS AND RECOMMENDATIONS

During these experiments, considerable differences were observed from time to time in the character of the boiling material and the manner in which it responded to crystallization procedures and equipment employed. Some low-grade materials proved easier to boil, cure and exhaust to low molasses purities than did others. The tendency towards conglomeration and formation of false grain, the rate of crystallization, the viscosities, etc., varied from factory to factory; also, differences were periodically noticed at the same factory. Because of these characteristics, the potential benefits to be secured from improved pan work may be expected to differ from factory to factory, but should be greatest where crystallization presents greatest difficulty and where the existing spread is largest between actual and Expected Purities. In general, it appears that those factories where the RS/A ratio is in the low ranges have a more difficult problem of crystallization and molasses exhaustion than those where the RS/A ratio is in the high end of the range. However, RS/A ratios do not appear to be the sole index of workability, nor the only natural factor influencing crystallization and molasses exhaustion.

These and other observations suggest that the requirements for optimum technique, instrumentation and auxiliary pan

installations are not necessarily the same for all factories. In short, a single set of detailed specifications for installations and technique may not be expected to apply equally well to all factories. Best results, therefore, should be expected only if the exact details for improving low-grade pan work are developed for each factory on the basis of local needs. As a corollary, the fact that any particular set of procedures, instruments or pan auxiliaries gives certain results at one factory does not necessarily mean that the same performance may be secured with the same procedural details at all other factories.

There are certain fundamental requirements, however, that apply in all cases, if improved low-grade results are to be achieved. The most important of these are listed briefly as follows:

- Maintenance of pan circulation independent of that produced by boiling.
- Dependable and precise control of boiling pressure.
- Dependable means for determining supersaturation.
- Use of seed suitable for establishing crystal crop.
- Selection of a massecuite purity level that assures just sufficient available

sucrose to produce a maximum crystal concentration, consistent with fluidity requirements. (The maximum crystal concentration that can be tolerated must be established for each factory by trial and error. In doing this, it is suggested that the increase in massecuite purity which, in most cases, will be required, be cautiously approached by raising purities in small successive steps.)

- Control of steam, condenser water and pan feed within limits that will preclude boiling irregularities and inconsistent results.
- Employment of pan technique optimums for control of crystal growth.

The recommendations to follow are made with these general requirements in mind. Exact details as to the make of circulator used, the number of circulator impeller elements provided, the type and make of boiling pressure regulator to be used, whether the absolute pressure or vacuum is controlled, just what type of BPE instrument or other device should be selected, etc., can best be decided on the basis of local factory conditions and general policies, and, therefore, such specific details have been omitted in our recommendations. Also, no recommendations are made with respect to desired pan characteristics since it is assumed that existing pans will be used with the new technique to obtain the improved results.

The provisions recommended in the following sections, it is believed, cover the principal considerations necessary for successful inauguration of the improved low-grade boiling technique, and their adoption should result in the better molasses exhaustion and the attractive financial benefits indicated elsewhere in this report.

GENERAL RECOMMENDATIONS 1. Before attempting use of Fondant seed and the improved technique, install the equipment required for its successful operation, as later listed.

2. Secure services of the HSPA Experiment Station, after installations have been completed, to assist the factory staff in working out specific details of procedure that will best fit local requirements.

3. Standardize procedures and institute a plan of supervisory control that will assure that standard procedures are consistently carried out by the factory operators.

SPECIFIC RECOMMENDATIONS

1. Provision of Auxiliary Equipment

- Provide an independent means for augmenting natural pan circulation—by installation of either a suitable mechanical circulator or an adequate steam agitation coil installation under the calandria. This is essential in the seed pans and highly desirable also in the finishing pans.
- Provide a streamline bottom on seed pans in which steam agitation coils are used as the means for producing supplementary circulation. Deep conical bottoms preclude good results, either with or without supplementary steam agitation.
- Provide **for all low-grade pans** either an absolute pressure, or a vacuum control that is both sensitive and dependable. This control instrument should regulate boiling pressure consistently within limits of ± 0.15 inch Hg., and preferably closer.
- On **seed pans not** equipped with mechanical circulators provide an automatic controller to vary pan

- boiling pressure precisely in accordance with a pre-established time-pressure cycle of change. Accuracy of regulation should be within limits of ± 0.15 inch Hg. of the stipulated pressure change curve. This control is not required on low-grade finishing pans.
- Provide a dependable, sensitive and precise means which will determine within limits of $\pm 0.05^\circ$ (about $\pm 1^\circ$ F. in terms of BPE) the relative supersaturation of the seed pan boiling material, during first half of boiling period. This is desired, but not required on the low-grade finishing pans.
 - Provide recording gauges that may be read to a reasonably close accuracy on the calandria steam (pressure-vacuum), the pan boiling pressure, the pan boiling temperature and the circulator drive motor load (if any). While these records are not absolutely essential, they are strongly recommended as a valuable aid to supervisory follow-up.
 - Provide suitable equipment for conveniently preparing Fondant seed slurry.
 - Provide apparatus for volumetric determination of massecuite crystal concentration (shrinkage determination).
 - Provide a convenient means for withdrawing a sample of massecuite from the pan.
 - Provide means for quickly introducing seed slurry into the graining charge.
- ## 2. Pan Operational Supplies
- Maintain a reasonably uniform steam pressure on the supply to the calandria and steam agitation coils.
 - Provide for adequate condenser water at a reasonably uniform pressure.
 - See that pan feed material is always free of crystals and of a uniformly standard density.
 - Provide an individual vacuum pump for the massecuite seed pan.
- ## 3. Technique
- Use C and H Fondant and Icing sugar, mixed into a homogeneous slurry, for seeding.
 - Use graining charge purity 7-12 points above massecuite purity. After trials determine the exact figure, standardize on a single purity within suggested range.
 - Standardize on a minimum graining charge volume.
 - Select correct final massecuite purity to just produce the maximum crystal crop concentration permissible with the fluidity requirements imposed by the equipment.
For most factories this will require a higher purity low-grade massecuite than is now standard. In determining the correct massecuite purity, it is recommended that existing purities be raised only in modest increments, rather than by a single step, until a crystal concentration optimum for local requirements is established. After this is established, the purity will still require changing from time to time to fit variations in Expected Purity, as outlined in the section on "Relation of Molasses Exhaustion to Crystal Concentration and Massecuite Purity."
 - Boil both seed and final strikes "close" and use no "boiling water."
 - Do not exceed 26 inches vacuum during the boiling cycle.

- Drop finished strike as "stiff" as pan crystallizers and centrifugals will permit, and at a temperature that prevails with a pan vacuum of about 25½ inches Hg.
- Cure strikes at least 60 hours—and more if possible.
- For 1700 rpm centrifugal machines, tentatively adopt a final grain size of 0.25–0.30 mm.
- Use the pattern of pan manipulations outlined earlier and charted in Figures 1 and 2 of this report. (One pattern has been developed for pans equipped with mechanical circulators and one for pans equipped with steam agitation coils.)

Some expenditures will be required to carry out these provisions. In addition to the moderate capital investment, a small increase in costs may be necessary to provide for more laboratory analyses. Also, greater supervisory attention to

pan floor work will be required, at least to start with, in order to assure adequate directive control of the technique. The cost of all these, however, appears minor compared with the potential returns of \$1 or more per ton of raws, which have proved possible in factory test work recently conducted by the writers.

In conclusion emphasis should be given to the fact that there is little room for compromising on what is recommended, if the full benefits of the proposed technique are to be consistently realized. The plan of operation has been designed to require the minimum investment and still secure the potential benefits. Failure to provide the needed equipment or follow the basic procedures can only result in failure of the project, and a consequent loss of substantial benefits. However, if the necessary equipment is provided and the technique and procedures herein recommended properly carried out, a very substantial saving to the industry appears assured.

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Appendix

Section 1.

EXPERIMENTS AT OAHU SUGAR COMPANY FACTORY *

As already mentioned, the writers conducted some 28 experiments on low-grade pan-boiling in Oahu Sugar Company's factory at Waipahu, using a pan technique similar to that developed for low grades at the Crockett refinery, and discussed in detail in the report "Low-Grade Sugar Crystallization" by E. C. Gillett, issued in May, 1948.

These tests were largely exploratory in nature, with the objective of determining the boiling procedure details that are optimum for obtaining a minimum molasses purity and maximum low-grade sugar purity.

BASIS OF COMPARISON In starting this series of tests it was first necessary to become acquainted with the equipment and materials to be handled at the Oahu Sugar Company's factory. Results secured from such preliminary experimental strikes as were boiled for this purpose, of course, are not valid for establishing the merits of the proposed technique, and therefore, have been excluded from the comparisons. Also, in the course of the six weeks' experimentation, several of the test strikes were badly damaged by accidental dilution from a syrup run-over at the crystallizer station and hence the data from these also had to be excluded from comparisons.

Although the technique used for the balance of the strikes was not fully standardized (since it was necessary to determine by "trial and error" the exact details of boiling and massecuite specifications required for optimum results), in most cases the deviations from optimum were not sufficient to justify their exclusion from the general over-all comparison with regular factory results. The average data from a group comprising 19 of these latter experimental strikes, therefore, has been used as one basis of comparison. These are designated as "General Group." (Table I).

A careful scrutiny of all the data obtained from these 19 strikes indicates that 10 very closely approached what appears to be optimum with respect to details of production procedure and massecuite quality. The results obtained from these 10 tests in which perfected procedure was most nearly approached, have been selected for comparison with regular factory results for the same period. It is believed that such a comparison is quite valid and may be accepted with considerable assurance as a conservative index of the improvement that may be accomplished by adoption of the suggested pan technique. Additional experimentation to establish with greater exactness the optimum procedural details and to accumulate more comparative data, is desirable, however. We believe such further trials may show greater improvements than were secured in these preliminary special tests, particularly after the present program of expanding and improving the crystallizer station at the Oahu sugar factory is completed.

A brief summary follows of significant data relating to each of the 10 experimental

* The writers are greatly indebted to George Bromley of the Oahu Sugar Company for his generous cooperation and able assistance in carrying out the test program.

Table I
Summary of Comparative Results
Oahu Sugar Company, 7/31/48 to 9/4/48
General Group—19 test strikes

	Experimental	Regular	Difference
Mass. Purity.....	60.8	58.6	+ 2.2
Crystall Yield (% on Mass. Solids).....	45.5	39.4	+ 6.1
Low-grade Sugar Purity.....	84.7	80.9	+ 3.8
Final Molasses Purity, Suc./Rds.....	35.07	36.96	- 1.89
Expected Purity.....	29.81	29.69	
Points above Expected Purity.....	5.26	7.27	- 2.01
RS/A Ratio.....	1.84	1.87	
Hours in Crystallizer.....	56	36	+20

strikes that were produced under conditions most nearly approaching optimum. The average result from these 10 experimental strikes is compared with the average of regular factory strikes produced during the same period, to indicate the improvement. (Table II).

Note 1: Crystallizer Curing Time

The longer curing period of some of the experimental strikes occurred during week-end storage. Because of lack of heating capacity in the crystallizer water circulating system the massecuite temperature during shut-down tended to drop below the safe temperature limit. Therefore, to prevent the massecuites from becoming too stiff because of the low temperature during shut-down, they were lubricated by generous additions of water. This practice, of course, acts to raise the mother liquor purity and several spot checks indicated that the normal advantage of the longer curing period is, in the case of most of these strikes, more

Table II
Special Group —10 Strikes—Summary of Experimental Strike Data
(Oahu Sugar Co. 7/31/48 to 8/14/48)

Molasses									
Test No.	Sugar App. Purity	App. Purity	Ref. Suc. Purity	Expt. Suc. Purity	Points Above Expt.	RS/A Ratio	Mass. Purity	Per cent† Cryst. Yield	Cryst. Hours
3	85.1	29.3	34.11	29.13	4.98	2.03	61.2	45.8	60
3A	89.9	29.4	35.65	30.83	4.82	1.62	60.1	44.1	24
4§	80.4	29.9	36.16	31.00	5.16	1.59	65.4	51.4	24
5	91.0	29.1	34.88	29.11	5.77	2.04	62.4	47.7	72
5A	84.3	28.3	34.11	29.00	5.11	2.07	61.4	46.8	67
6	88.0	27.4	33.20	28.74	4.46	2.15	63.3	50.2	61
7	84.9	29.5	34.52	29.20	5.32	2.01	61.9	46.7	29
9	84.4	28.7	34.42	29.77	4.65	1.85	59.7	44.2	29
10	82.5	28.4	34.41	29.34	5.07	1.97	60.5	45.4	78
10A	87.5	27.1	33.31	29.31	4.00	1.98	60.5	46.5	80
Avg	85.8‡	28.7	34.47	29.54	4.93	1.93	61.6	46.9	52
Avg. Reg. Strikes*	81.2‡	32.4	37.00	29.57	7.43	1.91	58.1	38.6	32
O. S. Co. 7/30/48 to 8/14/48									
Improvement	+ 4.6	- 3.7	- 2.53	.....	- 2.50	.....	.....	+ 8.3	..

* Experimental strikes excluded.

† Calculated on SJM Formula, using apparent purities and assuming a crystal purity of 99.

‡ Normal purging time 40 minutes.

§ Straight Strike. All others are cut strikes.

than offset by the water additions. Therefore, comparison between the curing time of the experimental and regular strikes appears to be meaningless.

Note 2: Boiling Time

In general, the Waipahu staff believed that the time actually required to boil low-grade massecuites with the improved technique for the experimental strikes is about 10–15 per cent less than for regular strikes. Boiling times have been excluded for the preceding tabulation, however, because regular records for pan hours are misleading, due to the irregularities where the pans are delayed by lack of boiling material, and other factory conditions. Furthermore, seed strikes were boiled and cut into two pans for completion, and, due to the differences in the two pans (heating surface, circulator, bottom, etc.) exact statistical comparisons of boiling times are difficult. It is safe to say, however, that at least no sacrifice of low-grade pan net capacity is required by the improved technique, and most probably an increase in net pan floor capacity should result. This is in spite of the somewhat greater daily volume of low-grade massecuite resulting from the higher massecuite purity.

SUMMARY OF BENEFITS 1. *Improved Molasses Exhaustion*

On the basis of the comparative results of regular factory work and the results of the test strikes boiled and cured with the present limited capacity crystallizer station, an improvement in the order of 2 to 2½ points in molasses exhaustion should result from inauguration of the suggested low-grade pan technique. While improvement and expansion of the Waipahu crystallizer station is expected to give better results with the **regular** technique, it is believed the **improved** technique should show a still greater relative improvement than the 2 to 2½ points shown in the tabulations. This latter opinion is not pure surmise but is indicated by the results of tests which by special arrangement were cured approximately 80 hours without over lubrication (with water). The final purity improvement for a like pan crystal concentration in these strikes averaged about 25 per cent more than for the shorter curing time.

At prices of sugar and molasses existing at the time of these experiments, an improvement of two points in molasses exhaustion should increase commercial sugar yield value approximately by \$1.20 per ton of raws produced. On a crop of 80,000 tons, this would be equivalent to an approximate saving of \$96,000 annually, for this single factory. In addition, however, considerable added economy is possible as result of low-grade sugar improvement and better pan house performance.

2. *Improved Purity of Low-Grade Sugar*

With the suggested boiling technique, a low-grade sugar purity of about 85°, with 40 minutes spinning time on 1700 R.P.M. machines is assured at Waipahu, on the average. This is about 4–5 points higher than the sugar regularly produced and presents the following advantages:

- With an increase in the low-grade massecuite purity, a larger amount of low-grade sugar obviously is produced. However, the purity of this sugar is higher than the normal low-grade sugar, and, because of this, it may be possible to reduce the circulating load of non-sugars in both the raw and low-grade systems. The extent of this change in non-sugar circulating load is, of course, subject to

calculation and depends upon the purity changes of the massecuite and sugar. Any reduction in circulating load naturally decreases capacity demands on the pans, centrifugals and crystallizers.

- The better grain of the sugar permits the centrifugal drying time to be cut from 15 to 30 per cent and at the same time maintain a sugar purity above 80. This is important, particularly whenever the factory is overburdened with low-grade products (due to low purity juice or high grinding rate), as it avoids the ordinary penalty of either resorting to lighter density low-grade massecuites, or accepting a pan house congestion due to the vicious cycle of increasing non-sugar recirculating load.
- The better quality grain produced by the improved boiling technique should produce a commercial sugar of better refining quality, since low-grade sugar is used for the raw sugar seed.

3. *Pan Capacity*

On those tests where boiling rate observations could be taken, the time required to boil a low-grade strike with the suggested improved technique is 10-15 per cent less than required by normal Waipahu technique. This increase in pan capacity may be attributed to the following factors.

- Less evaporation is required per unit of final massecuite boiled. This reduction is possible because the improved technique eliminates the necessity for using "boiling water" or light density feed.
Not only does elimination of boiling water and light density feed give increased pan capacity, but it results in better crystal uniformity and improved control of crystal crop population since the tendency to melt grain is greatly reduced.
- The rate of mother liquor desugarization is maintained at a maximum because the technique requires that the crystal surface area per unit volume of mother liquor be maintained at a maximum. (Greater pan purity drops per unit of boiling time are obtained under these conditions.)
- Crystals grow faster in the higher purity graining charges that are maintained. The crystal surface increases more rapidly than does that in lower purity graining charges with the result that desugarization is faster. This has the further advantage of hastening the entire crystal growth reaction through the early growth period, where difficulties are most apt to develop with crystal crop quality.
- Crystal growth proceeds to completion faster with the higher massecuite purity required by the improved techniques.

It appears from field observations that these favorable capacity factors will at least compensate for the increase of low-grade massecuite volume resulting from increased massecuite purities.

PAN EQUIPMENT AND CONTROLS The Waipahu factory was selected for our initial experiments particularly because their boiling controls and pan equipment appeared to be most adequate and suitable to meet the requirements of the improved technique to be tested.

The pans are equipped with **three element Webre** Circulators and, on the circulator drive motors are installed ammeters which indicate accurately the consistency of the boiling massecuite. Calandria pans which **are** equipped with circulators have proved at both Crockett and here in the Islands to be much simpler in operation and

control when applying the improved technique of boiling. As indicated previously, calandria pans **not** equipped with adequate mechanical circulation require a more complicated technique of handling in order to secure results that approach those obtained from pans with circulators.

The Waipahu pans are also equipped with the instruments and control devices essential to the successful application of the improved boiling techniques, such as absolute pressure regulators, mercury vacuum gauges, and two-pen boiling point elevation recorders. By the use of the last, a satisfactory indication of supersaturation could be obtained from the BPE inasmuch as a constant absolute pressure was maintained.

By use of these or other equivalent controls, and by taking full advantage of the possibilities offered by the mechanical circulator, it was found possible to perfect a procedure of pan manipulation which is simple, reproducible and may confidently be turned over to the regular pan men for commercial operation. In fact, the factory pan men at Waipahu adopted the technique successfully as regular factory practice after one week's training.

In addition to the equipment and control instruments, it was, of course, necessary to provide a means to prepare a Fondant seed slurry, which is used in connection with the technique. Temporary equipment from the Experiment Station was used during the tests. This equipment consisted primarily of a small portable "Lightning" stirrer and a container in which to mix a saturated syrup and the Fondant seed.

In addition, the shrinkage apparatus described on page 27 of E. C. Gillett's report on Low-Grade Sugar Crystallization (issued May of 1948), was used to determine the crystal content of the massecuite. These shrinkage tests by which the surplus fluid content of the massecuite was determined, provided a practical volumetric check on the crystal concentration of the massecuite. It was found quite useful to determine with this instrument the crystal concentration at several stages of the boiling period, and at the time of dropping the strike; also after the strike had been cured.

This instrument is recommended as an important aid to supervisory control over regular factory pan work, since it provides a simple, convenient and reliable means of checking the quality of the massecuite boiled with respect to its grain concentration, and consequently, its molasses exhaustion potential.

PANS AND TECHNIQUE USED The Waipahu factory has two low-grade pans, both of which were used in connection with boiling these test strikes. All seed strikes, however, were boiled in No. 3 pan which has a streamlined bottom. Table III gives data relating to size and capacity of these pans that may be of interest.

Table III

	Pan No. 2	Pan No. 3
Diameter.....	14' 1"	14' 9"
Square feet heating surface.....	2018	3076
Cubic feet (total).....	1800	1800
Diameter of center well.....	4'	5'
Diameter of Webre Circulator.....	4'	5'
R.P.M. of Webre Circulator.....	42	50
Average height of massecuite above calandria when finished.....	63 ³ / ₄ '	6'
Cubic feet of massecuite boiled.....	1500	1500

In addition to the instruments and controls already mentioned, these pans were both equipped with small massecuite pressure filters from which samples of "hot" molasses were obtained at the end of the strike.

While a few single strikes were boiled in the first phases of the experimental work, most of the final massecuites were cut strikes. Sufficient seed was introduced in No. 3 pan and a seed strike was boiled. Half of this strike was then transferred to No. 2 pan and both pans were boiled to a final massecuite volume of 1500 cubic feet, thus producing a total of 3000 cubic feet of massecuite per seed strike. In most instances, the writers followed through the seed strike closely and then turned over the cut footings to the regular pan men to complete.

1. Size and Purity of Graining Charge

Although there was some variation from strike to strike in the graining charge size, as a general rule only sufficient footing was drawn in to insure calandria coverage after concentration to seeding saturation. The graining charge usually represented about 42 per cent of the 1500 cubic feet seed strike, and 21 per cent of the final massecuite.

In the case of most of the strikes boiled, the graining charge purity ranged between 67°-74° AP. An apparent purity of about 70°, seems to be near the optimum for Waipahu boiling materials, and, with such a purity, the crystals in the strike consistently grew, within an hour, to about .12 mm.

2. Seed Preparation

C & H Fondant and Icing sugar was used as seed in boiling all experimental strikes. After several trial strikes, it was found that the optimum amount of seed for 3000 cubic feet of massecuite was approximately eight pounds. The final massecuite produced from this amount of seed contained approximately 47 per cent (by weight on massecuite solids) of 99° purity crystals, which average about .30 mm in length.

The seed was introduced into the graining charge, at the proper degree of supersaturation, in the form of a slurry. This slurry was prepared by thoroughly dispersing the Fondant seed particles in a **saturated** high purity syrup. Evaporator thick juice was used as a base for the saturated syrup and raw sugar was added until the thick juice was fully saturated at a temperature of approximately 105° F. The "Lightning" stirrer mentioned previously was used to expedite preparation of this saturated solution.

The seed slurry was prepared in saturated syrup in accordance with the procedure described in a preceding section and was introduced into the pan at the proper time through a two-inch pipe connected to the bottom of the pan. This line was equipped with a funnel and quick opening valves, and great care was exercised to avoid drawing air into the pan with the seed so that shock grain would not be formed. (Further details of seed slurry preparation may be found on page 119.)

3. Seed Point Determination

The Oahu Sugar Company pans have a central vacuum system and, because of this, it was necessary to coordinate the stopping and starting of other pans so that the vacuum on No. 3 pan (seed pan) did not fluctuate materially during the seeding and early grain growth period. With the vacuum automatically controlled at a specific level, it was then possible to establish with the boiling point elevation instrument, the proper supersaturation for graining. For the various graining charge purities tried in the course of the experimental period, the indicated BPE ranged

between 19° F. and 24° F., with a vacuum of 25.8 inches. As long as it was possible to hold the vacuum steady at a specific level, this method of determining the proper seed point worked satisfactorily. However, any time the vacuum changed, a new boiling point elevation had to be selected as an index of the proper supersaturation. (A number of trials at different boiling point elevations were required before the optimum figure for seed introduction was established.)

Just prior to reaching the selected boiling point elevation, about two quarts of raw sugar crystals were introduced into the graining charge and pan proofs were examined immediately thereafter to determine if the crystals were melting, or if they retained their sharp edges. This was found to be a practical means of checking the minimum supersaturation indicated for graining by the boiling point elevation instrument. As soon as proof examination of a raw crystal indicated sharp edges and surfaces of the raw crystals were smooth, the Fondant seed slurry was introduced.

4. Grain Crop Establishment

During the early part of the strike when the seed is small and the ratio of aggregate grain surface area to mother liquor volume is extremely small, it is absolutely essential that the supersaturation be maintained well within the metastable zone, otherwise conglomeration and a secondary crop of crystals is apt to develop. No actual boiling, therefore, was performed in the case of these tests for a period of $\frac{1}{2}$ hour after seeding. During this time the grain grew to a size of about .07 mm. from existing supersaturation. Of course, circulation was continually maintained by means of the mechanical circulator. At the end of $\frac{1}{2}$ hour, steam was applied to the calandria for 10 minutes, which raised the supersaturation equivalent to about 1° F. BPE above the BPE value at seeding. The charge was then again allowed to circulate without boiling for another half hour, following which steam was again applied to the calandria for a period of 10 minutes. After this, again no boiling was performed for a period of 20 minutes.

This schedule of procedure was worked out on the basis of supersaturation control, as indicated by the prevailing BPE. In most cases the BPE dropped about 3° F. before the steam was applied, and boiling was permitted to proceed only sufficiently long to raise the BPE about 1° F. above the initial seeding BPE figure.

At the end of this initial growth period, the concentration of crystals had reached 50–65 per cent apparent volume and the size had reached approximately .15 mm. At this stage, experience indicated that it was quite safe to start boiling at a normal rate with a small feed, keeping the massecuite at a fairly stiff consistency.

5. Boiling

By maintaining a relatively high concentration of crystals in relation to massecuite fluid, the danger of false grain developing, or the grain conglomerating, is reduced to a minimum. The practice, therefore, was adopted of “carrying up” the strike with a feed which would maintain a fairly “stiff” or “close” massecuite (65–75 per cent apparent crystal volume as determined by the extraction shrinkage method) during the entire boiling period. This was very readily controlled by selecting the proper load to be carried on the circulator drive motor, as indicated by its ammeter.

6. Cutting

When the massecuite level reached approximately six feet above the calandria top tube sheet and the pan contained 1500 cubic feet, half of this seed was then transferred to No. 2 pan and both No. 2 and 3 pans again were boiled to a massecuite volume of 1500 cubic feet.

7. Final Concentration

Work by the HSPA Experiment Station has indicated that the mother liquor density of a massecuite should be as high as practicable if the maximum desugarization is to be obtained in the crystallizers. Therefore, it was found very advantageous to use the ammeter to determine the fluidity of the massecuite, during final concentration, preparatory to dropping. This permitted production, from strike to strike, of the stiffest possible massecuite that could be handled by the crystallizers. On the particular set-up at Waipahu, a load of 45 to 47 amps. proved about optimum for the experimental massecuites boiled.

Because the massecuite is maintained reasonably stiff after the initial grain growth period, the final concentration or "boiling down" time after the feed was shut off was accomplished in $\frac{3}{4}$ to $1\frac{1}{2}$ hours.

CRYSTALLIZER OPERATION The Waipahu factory was equipped at the time of these tests with eight Blanchard crystallizers of 1800 cubic feet maximum working capacity each. At the rate the factory was grinding during the experimental period, approximately 4500 cubic feet of low-grade massecuite was produced and purged daily. With the crystallizer capacity available, this meant that the average normal curing time could be only about 35 hours.

While the optimum curing time for obtaining maximum molasses exhaustion in commercial practice probably varies considerably with the character of the low-grade material handled, it is believed that the relatively short curing period at Waipahu necessitated some sacrifice in molasses exhaustion. Furthermore, there is evidence that a greater improvement in molasses exhaustion (compared with regular factory results with equal curing time) would have been obtained with the improved pan work had more crystallizer capacity been available.

The water heating system for the Blanchard crystallizers at the present time is inadequate to prevent the massecuite from over-cooling during long crystallizer curing periods, and because of this, strikes held in the crystallizer over the week-end must be diluted generously with water to prevent them from becoming too stiff. This also tends towards higher molasses purities and, when corrected, undoubtedly will aid in securing better molasses exhaustion. Experimental strikes which were held over the week-end, as mentioned earlier in this report, were diluted with water in most all cases, and this actually confused interpretation of results to a point where an attempt to evaluate longer curing time in the case of these tests is useless.

Four more 1800 cubic feet (HIW type) crystallizers are now being installed at the Oahu Sugar Company factory. With this increased crystallizer capacity, and an increase in the water heating system capacity, it is confidently expected that the Waipahu molasses will be brought much closer to expected purity with the improved pan technique, than will be possible otherwise.

CENTRIFUGALS The normal drying time for low-grade massecuites prior to handling experimental strikes was 40 minutes. Because the pan technique which had been standard for the Waipahu factory gave generally good results, a reasonably good purging sugar of approximately 80° purity was normal. In the experimental strikes with 40 minutes purging, the average ranged about 85° purity and, in some instances, rose as high as 91°. Since the low-grade centrifugal station is at times somewhat under capacity for a heavy low-grade load, the Waipahu management

was interested in the possibilities of increasing the capacity of this station without sacrificing low-grade sugar purity. With the good quality grain produced by the experimental strikes, it was found quite practical to accomplish this by cutting the centrifugal drying time.

In actual factory operation, results indicate that 30 minutes drying time produces a low-grade sugar purity of about 81° from massecuites boiled with the improved technique. A 33 $\frac{1}{8}$ per cent increase in low-grade centrifugal capacity has, therefore, been made possible if the same purity of low-grade sugar that previously had been normal for the factory is accepted. If, on the other hand, a reduction in the circulating load of non-sugar through the pan system is desired, the normal 40-minute purging time will give higher purity sugar, thus aiding towards this objective. The exact purging time probably can best be set on the basis of the incoming non-sugar load which, of course, is determined by rate of grinding and juice purity.

Detailed data for these tests at Oahu Sugar Company and similar data for the tests at Ewa, Waialua, and H. C. & S. Co. are in Section 8 of the Appendix.

Section 2.

LOW-GRADE MASSECUITE LOAD CALCULATIONS

The subject of low-grade massecuite volumes is of paramount importance where factories operating near maximum capacity in this respect are contemplating changes in processing conditions which may greatly increase or decrease the volume of low-grade massecuite handled. Tables have been compiled for the purpose of indicating the low-grade massecuite volume that may be expected at different low-grade massecuite purities, low-grade sugar purities, final molasses purities and syrup purities.

The calculations involved in the compilation of the tables are based on the SJM formula; therefore, whatever purity basis (i.e., refractometer pol purity or refractometer sucrose purity) is selected it must be used throughout for all purities in order that the values in the table approximate actual factory values. Comparisons between actual factory low-grade massecuite volumes and volumes calculated from the tables have shown a difference as high as 15 per cent in some instances. The calculated volume sometimes is higher and other times lower than the actual volume. This disparity between calculated volume and actual volume is attributable to a number of factors, namely suspended solids in syrup, non-representative sampling of low-grade sugar, incorrect estimates of differences between pol and sucrose purities, and inaccurate massecuite volume measurements. The last factor could easily account for a 25,000-cubic-foot error by a 100-cubic-foot error per strike for 250 strikes. Due to temperature of the massecuite and vacuum on a pan, most pan men are inclined to report a larger volume than actually exists.

METHOD OF CALCULATING LOW-GRADE MASSECUITE VOLUME

All calculations are based on the impurities in final molasses; therefore, the first step is necessarily one of calculating the impurities expected in the final molasses for a given set of conditions.

The following formula may be used to calculate the percentage of syrup impurities appearing in the final molasses:

$$\frac{100 (100 - M) (S - J)}{(100 - J) (S - M)} = y$$

Where: y = Final molasses impurities as per cent of syrup impurities
 M = Purity of final molasses
 S = Purity of commercial sugar
 J = Purity of syrup

Sample Calculation:

Basis: 100 tons sucrose in syrup, syrup purity 85.0, commercial sugar purity 98.5, and final molasses purity 35.0

$$\frac{100 (100 - 35.0) (98.5 - 85.0)}{(100 - 85.0) (98.5 - 35.0)} = 92.2\%$$

Then: $\frac{100}{.85} = 117.7$ tons of syrup

$117.7 - 100 = 17.7$ tons of impurities in syrup

$17.7 \times .922 = 16.3$ tons of impurities in final molasses

The next step is to calculate the impurities in a low-grade massecuite as percentage of the impurities in final molasses using the following formula:

$$\frac{100 (100 - J_L) (S_L - M)}{(100 - M) (S_L - J_L)} = y_L$$

Where: y_L = Impurities in low-grade massecuite as per cent of impurities in final molasses
 J_L = Purity of low-grade massecuite
 S_L = Purity of low-grade sugar
 M = Purity of final molasses

Sample Calculation:

Basis: Final molasses purity 35.0, low-grade massecuite purity 48.0, and low-grade sugar purity 66.0

$$\frac{100 (100 - 48) (66 - 35)}{(100 - 35) (66 - 48)} = 137.8\%$$

Then: $\frac{137.8}{100} \times 16.3 = 22.5$ tons impurities in low-grade massecuite

$$\frac{22.5 \times 100}{100 - 48} = 43.2 \text{ tons low-grade massecuite solids}$$

Tons of impurities in low-grade sugar and tons of low-grade sugar solids returned to commercial sugar system may be calculated from the above values.

$137.8 - 100 = 37.8\%$ impurities in low-grade sugar as per cent of impurities in molasses.

$$\frac{37.8}{100} \times 16.3 = 6.15 \text{ tons impurities in low-grade sugar}$$

$$\frac{6.15 \times 100}{100 - 66} = 18.05 \text{ tons low-grade sugar solids}$$

To convert tons low-grade massecuite solids to volume it is necessary to use the value for tons solids per cubic foot of massecuite corresponding to the massecuite refractometer solids.

LOW-GRADE MASSECUIE LOAD VARIATIONS A study of the compiled data indicates quite clearly the magnitude of changes in low-grade massecuite load that may be expected due to variations in purity of the syrup, massecuite, low-grade sugar, and final molasses.

For each 2.5 points purity increase of the syrup above 85.0 purity the low-grade massecuite load will be reduced by approximately 20 per cent, all other factors remaining constant. Most factory operators are cognizant of this fact, the usual practice being to increase the grinding rate to compensate for the reduced non-sugar load.

As a general rule, a one-point increase in low-grade massecuite purity will require approximately a two-point increase in low-grade sugar purity in order to maintain a constant low-grade massecuite load provided all other factors remain constant. This general rule emphasizes a point made in the section on "General Comments and Recommendations" concerning increases in massecuite purities which should be made in small increments so that the compensating effect of increased low-grade sugar purity may be fully realized.

Lowering of final molasses purities, other conditions being constant, will increase the low-grade massecuite load by returning to the process (in the low-grade sugar) additional impurities which eventually are re-boiled in the low-grade pan. These additional impurities are carried back into the process by the additional sucrose recovered from the molasses when its purity is decreased. The increase in massecuite load for a given decrease in molasses purity will of course be smaller when the low-grade sugar purity is higher because a smaller absolute amount of impurities will be carried along by the additional sucrose recovered. This relationship can be illustrated by reference to the accompanying tables. For example, a comparison is made below of the percentage increase in low-grade massecuite for a **decrease in final molasses purity from 40° to 35°** at low-grade sugar purities of 66° and 90°. All other conditions of course are constant.

Low grade sugar purity.....	66°	90°
Syrup purity.....	85	85
Low-grade massecuite purity.....	48	48
Percentage increase in low-grade massecuite load	10.2	1.5

It should be noted, however, that the application of the Gillett process of low-grade crystallization includes changes in several of the massecuite properties, i.e., increased massecuite purity, increased low-grade sugar purity, increased crystal yield, and decreased molasses purity. The mutual interdependence of these properties should be borne in mind when considering the effect of changes in only one of them on the low-grade massecuite load. Also it must be remembered that such changes affect the entire boiling system and not just the low-grade station alone.

Table IV

Low-grade Massecuite Load

Basis: 100 Tons sucrose in syrup, syrup refractometer sucrose purity 85.0, commercial sugar purity 98.5, final molasses refractometer sucrose purity 30.0.

Low-Grade Sugar Purity	Low-Grade Massecuite Purity								
	48	50	52	54	56	58	60	62	64
	Tons Low-Grade Massecuite Solids								
66	46.3	52.1	59.5	69.5	83.3	104.1	138.8	208.3	416.5
68	44.0	48.9	55.0	62.8	73.3	87.9	109.9	146.6	219.8
70	42.1	46.3	51.4	57.9	66.1	77.1	92.6	115.7	154.3
72	40.5	44.2	48.6	54.0	60.7	69.4	81.0	97.2	121.5
74	39.2	42.4	46.3	50.9	56.6	63.6	72.7	84.9	101.8
76	38.0	40.9	44.4	48.4	53.2	59.1	66.5	76.0	88.7
78	37.0	39.7	42.7	46.3	50.5	55.5	61.7	69.4	79.3
80	36.2	38.6	41.3	44.5	48.2	52.6	57.9	64.3	72.3
82	35.4	37.6	40.1	43.0	46.3	50.1	54.7	60.2	66.9
84	34.7	36.8	39.1	41.7	44.6	48.1	52.1	56.8	62.5
86	34.1	36.0	38.1	40.5	43.2	46.3	49.8	54.0	58.9
88	33.6	35.3	37.3	39.5	41.9	44.7	47.9	51.6	55.9
90	33.1	34.7	36.6	38.6	40.8	43.4	46.3	49.6	53.4
	Refractometer Solids				Tons Solids per 100 Cubic Feet				
					93				
					94				
					95				
					96				

Table V

Low-grade Massecuite Load

Basis: 100 Tons sucrose in syrup, syrup refractometer sucrose purity 87.5, commercial sugar purity 98.5, final molasses refractometer sucrose purity 30.0.

Low-Grade Sugar Purity	Low-Grade Massecuite Purity								
	48	50	52	54	56	58	60	62	64
	Tons Low-Grade Massecuite Solids								
66	36.9	41.5	47.4	55.3	66.3	82.9	110.5	165.9	331.7
68	35.0	38.9	43.8	50.0	58.4	70.0	87.5	116.7	175.0
70	33.5	36.9	40.9	46.1	52.6	61.4	73.7	92.1	122.9
72	32.3	35.2	38.7	43.0	48.3	55.3	64.5	77.4	96.8
74	31.2	33.8	36.9	40.5	45.1	50.7	57.9	67.6	81.1
76	30.3	32.6	35.4	38.5	42.4	47.1	53.0	60.5	70.6
78	29.5	31.6	34.0	36.9	40.2	44.2	49.1	55.3	63.2
80	28.8	30.7	32.9	35.4	38.4	41.9	46.1	51.2	57.6
82	28.2	29.9	31.9	34.2	36.9	39.9	43.6	47.9	53.3
84	27.6	29.3	31.1	33.2	35.5	38.3	41.5	45.2	49.8
86	27.2	28.7	30.3	32.3	34.4	36.9	39.7	43.0	46.9
88	26.8	28.1	29.7	31.5	33.4	35.6	38.1	41.1	44.5
90	26.4	27.6	29.2	30.7	32.5	34.6	36.9	39.5	42.5

Table VI

Low-grade Massecuite Load

Basis: 100 Tons sucrose in syrup, syrup refractometer sucrose purity 90.0, commercial sugar purity 98.5, final molasses refractometer sucrose purity 30.0.

Low-Grade Sugar Purity	Low-Grade Massecuite Purity								
	48	50	52	54	56	58	60	62	64
	Tons Low-Grade Massecuite Solids								
66	27.6	31.0	35.4	41.3	49.6	62.0	82.7	124.1	248.1
68	26.2	29.1	32.8	37.4	43.7	52.4	65.5	87.3	130.9
70	25.1	27.6	30.6	34.5	39.4	45.9	55.2	68.9	91.9
72	24.1	26.3	29.0	32.2	36.2	41.3	48.3	57.9	72.4
74	23.4	25.3	27.6	30.3	33.7	37.9	43.3	50.6	60.6
76	22.6	24.4	26.5	28.8	31.7	35.2	39.6	45.3	52.8
78	22.0	23.7	25.4	27.6	30.1	33.1	36.8	41.3	47.2
80	21.6	23.0	24.6	26.5	28.7	31.3	34.5	38.3	43.1
82	21.1	22.4	23.9	25.6	27.6	29.9	32.6	35.9	39.9
84	20.7	21.9	23.3	24.8	26.6	28.7	31.0	33.8	37.2
86	20.3	21.5	22.7	24.1	25.7	27.6	29.7	32.2	35.1
88	20.0	21.0	22.2	23.5	25.0	26.6	28.5	30.7	33.3
90	19.7	20.7	21.8	23.0	24.3	25.9	27.6	29.6	31.8

Table VII

Low-grade Massecuite Load

Basis: 100 Tons sucrose in syrup, syrup refractometer sucrose purity 85, commercial sugar purity 98.5, final molasses refractometer sucrose purity 35.0.

Low-Grade Sugar Purity	Low-Grade Massecuite Purity								
	48	50	52	54	56	58	60	62	64
	Tons Low-Grade Massecuite Solids								
66	43.2	48.6	55.6	64.8	77.6	97.2	129.9	194.2	389.0
68	41.4	46.0	51.7	59.2	69.0	82.9	103.6	138.1	207.0
70	39.9	44.0	48.8	54.9	62.7	73.2	87.8	110.0	146.5
72	38.7	42.2	46.5	51.6	58.0	66.4	77.4	92.5	116.1
74	37.6	40.8	44.5	48.9	54.4	61.0	70.0	81.5	97.9
76	36.7	39.6	42.9	46.7	51.5	57.2	64.4	73.6	85.7
78	35.9	38.6	41.5	44.9	49.0	54.0	60.0	67.4	77.1
80	35.3	37.7	40.4	43.4	47.1	51.3	56.4	62.7	70.5
82	34.7	36.9	39.4	42.1	45.4	49.2	53.7	59.0	65.6
84	34.2	36.2	38.5	41.0	44.0	47.3	51.3	55.9	61.5
86	33.7	35.6	37.7	40.0	42.6	45.7	49.3	53.3	58.2
88	33.2	35.1	37.0	39.1	41.5	44.3	47.5	51.2	55.4
90	32.8	34.6	36.4	38.3	40.6	43.1	46.1	49.3	53.1

Refractometer
Solids

Tons Solids per
100 Cubic Feet

93

4.36

94

4.42

95

4.49

96

4.56

Table VIII

Low-grade Masecuite Load

Basis: 100 Tons sucrose in syrup, syrup refractometer sucrose purity 87.5, commercial sugar purity 98.5, final molasses refractometer sucrose purity 35.0.

Low-Grade Sugar Purity	Low-Grade Masecuite Purity								
	48	50	52	54	56	58	60	62	64
	Tons Low-Grade Masecuite Solids								
66	34.4	38.7	44.4	51.6	61.8	77.4	103.6	155.0	310.0
68	33.0	36.6	41.2	47.2	54.9	66.0	82.6	110.4	165.0
70	31.8	35.1	38.9	43.7	50.0	58.4	70.0	87.6	116.8
72	30.8	33.6	37.0	41.1	46.2	52.8	61.6	73.7	92.5
74	30.0	32.5	35.5	38.9	43.3	48.6	55.7	65.0	77.9
76	29.2	31.5	34.2	37.2	41.0	45.5	51.3	58.7	68.2
78	28.6	30.7	33.1	35.8	39.0	43.0	47.8	53.6	61.4
80	28.1	30.0	32.2	34.6	37.5	40.8	44.8	50.0	56.2
82	27.6	29.4	31.4	33.6	36.2	39.2	42.8	47.0	52.3
84	27.2	28.9	30.7	32.7	35.1	37.7	40.8	44.5	49.0
86	26.8	28.4	30.1	31.9	33.9	36.4	39.3	42.5	46.3
88	26.5	28.0	29.5	31.1	33.1	35.3	37.8	40.8	44.1
90	26.2	27.6	29.0	30.5	32.4	34.4	36.7	39.3	42.3

Table IX

Low-grade Masecuite Load

Basis: 100 Tons sucrose in syrup, syrup refractometer sucrose purity 90.0, commercial sugar purity 98.5, final molasses refractometer sucrose purity 35.

Low-Grade Sugar Purity	Low-Grade Masecuite Purity								
	48	50	52	54	56	58	60	62	64
	Tons Low-Grade Masecuite Solids								
66	25.6	28.8	33.0	38.4	46.0	57.6	77.0	115.2	230.5
68	24.5	27.3	30.6	35.1	40.9	49.1	61.4	82.0	122.8
70	23.7	26.1	28.9	32.5	37.2	43.4	52.0	65.2	86.8
72	22.9	25.0	27.6	30.6	34.4	39.4	45.8	54.8	68.8
74	22.3	24.2	26.4	29.0	32.2	36.1	41.5	48.3	58.0
76	21.7	23.5	25.4	27.7	30.5	33.9	38.2	43.7	50.8
78	21.2	22.9	24.6	26.6	29.1	32.0	35.6	39.9	45.9
80	20.9	22.3	23.9	25.7	27.9	30.4	33.4	37.2	41.8
82	20.6	21.8	23.3	25.0	26.9	29.2	31.8	35.0	38.9
84	20.3	21.4	22.8	24.3	26.1	28.0	30.4	33.1	36.5
86	20.0	21.1	22.3	23.7	25.2	27.1	29.2	31.6	34.5
88	19.7	20.8	21.9	23.2	24.6	26.3	28.2	30.3	32.8
90	19.5	20.5	21.6	22.7	24.1	25.6	27.4	29.2	31.5

Table X

Low-grade Massecuite Load

Basis: 100 Tons sucrose in syrup, syrup refractometer sucrose purity 85.0, commercial sugar purity 98.5, final molasses refractometer sucrose purity 40.0.

Low-Grade Sugar Purity	Low-Grade Massecuite Purity								
	48	50	52	54	56	58	60	62	64
	Tons Low-Grade Massecuite Solids								
66	39.2	44.2	50.4	58.8	70.5	88.0	117.7	176.5	352.8
68	38.1	42.2	47.5	54.3	63.4	76.0	95.0	126.7	190.0
70	37.0	40.7	45.2	50.9	58.1	67.8	81.5	101.8	135.8
72	36.2	39.5	43.4	48.3	54.3	62.0	72.4	86.8	108.6
74	35.5	38.5	41.9	46.1	51.3	57.6	65.9	76.9	92.3
76	34.9	37.6	40.7	44.4	48.8	54.3	61.0	69.8	81.5
78	34.4	36.8	39.7	43.0	46.9	51.5	57.3	64.5	73.6
80	33.9	36.2	38.8	41.7	45.2	49.4	54.3	60.3	67.8
82	33.5	35.7	38.0	40.7	43.8	47.5	51.8	57.0	63.3
84	33.2	35.2	37.3	39.8	42.6	45.9	49.7	54.3	59.6
86	32.9	34.7	36.7	39.0	41.6	44.6	48.1	52.1	56.7
88	32.6	34.3	36.2	38.3	40.7	43.4	46.5	50.1	54.3
90	32.3	34.0	35.7	37.6	39.9	42.4	45.2	48.5	52.2
			Refractometer Solids	Tons Solids per 100 Cubic Feet					
			93	4.36					
			94	4.42					
			95	4.49					
			96	4.56					

Table XII

Low-grade Masecuite Load

Basis: 100 Tons sucrose in syrup, syrup refractometer sucrose purity 90.0, commercial sugar purity 98.5, final molasses refractometer sucrose purity 40.0.

Low-Grade Sugar Purity	Low-Grade Masecuite Purity							
	48	50	52	54	56	58	60	62
	Tons Low-Grade Masecuite Solids							
66	23.4	26.4	30.1	35.2	42.2	52.6	70.4	105.6
68	22.8	25.2	28.4	32.5	37.9	44.5	56.8	75.8
70	22.1	24.3	27.0	30.4	34.7	40.5	48.7	60.9
72	21.7	23.6	26.0	28.9	32.5	37.1	43.3	51.9
74	21.2	23.0	25.1	27.6	30.7	34.5	39.4	46.0
76	20.9	22.5	24.3	26.6	29.2	32.5	36.5	41.7
78	20.6	22.0	23.7	25.7	28.1	30.8	34.3	38.6
80	20.3	21.7	23.2	24.9	27.0	29.5	32.5	36.1
82	20.0	21.4	22.7	24.3	26.2	28.4	31.0	34.1
84	19.9	21.1	22.3	23.8	25.5	27.5	29.7	32.5
86	19.7	20.8	22.0	23.3	24.9	26.7	28.8	31.2
88	19.5	20.5	21.7	22.9	24.3	26.0	27.8	30.0
90	19.3	20.3	21.4	22.5	23.9	25.4	27.0	29.0

Section 3.

NON-AQUEOUS FONDANT SLURRIES

Although Fondant seed slurries prepared from saturated sugar liquor have given satisfactory pan seeding results, there are certain steps in the preparatory procedure which are time-consuming and critical, and, therefore, undesirable where the pan operator has numerous auxiliary duties. In particular, maintenance of the sugar liquor vehicle at the saturation point requires very careful attention. The success of the complete seeding operation, which may affect two or three low-grade strikes, can be limited or nullified by the inadvertent use of an unsaturated sugar liquor, which may dissolve much of the Fondant seed thereby producing insufficient seed in the graining charge. To eliminate the possibility of errors of this type and at the same time simplify the procedure, the suggestion was made that a non-aqueous vehicle requiring no saturation might be suitable for suspending the Fondant seed. The first non-aqueous vehicle used was linseed oil, the tests being conducted at Hutchinson Plantation Company by W. E. Smith and A. Wulfekuhler. The grain resulting from the use of the linseed oil slurry was of satisfactory quality and was unexpectedly present in much greater numbers than would have normally been produced by a like amount of Fondant seed suspended in a saturated sugar solution. As a result of these tests the Experiment Station, in conjunction with Crockett, proceeded to make a thorough study to determine the most suitable non-aqueous vehicle, or vehicles, for use as a dispersing medium for Fondant seed.

VEHICLE SELECTION In order that a non-aqueous vehicle be satisfactory and acceptable for use in a food processing plant it must meet certain pure food law requirements and, in addition, the cost should be low enough to make its use economically attractive when compared with the standard saturated sugar liquor.

Furthermore, the vehicles should not have a taste-contaminating effect either on the sugar or on the final molasses, particularly the latter, since it is sold directly to

the consumer and is not subject to further processing. Contamination of molasses by petroleum products such as Diesel oil, kerosene, or gasoline in concentrations as small as .005 to .02 per cent has caused complaint by molasses consumers and has been detected in the laboratory by taste tests.

A number of non-aqueous vehicles were investigated and by the process of elimination the field was narrowed down to two, both of which appear to have generally satisfactory qualities. The two vehicles are isopropyl alcohol, 99 per cent (1 per cent water) and white oil No. 3, the latter being a U.S.P. petroleum oil widely used in the food industry. The costs of these vehicles are approximately equal, being in the range of 85 to 95 cents per gallon. While this cost of the non-aqueous vehicle would represent an added expense for the boiling process, it would be more than offset by the saving resulting from the reduction in the amount of Fondant sugar required.

FACTORY TEST RESULTS Factory tests using the selected non-aqueous vehicles in place of saturated sugar liquor were conducted at Crockett, Oahu Sugar Company, Waialua Agricultural Company and Kahuku Plantation Company. Isopropyl alcohol slurries produced a crystal crop comparable in uniformity with that produced by saturated sugar liquor slurries, while the oil slurries tended to give a somewhat more irregular crystal crop. Also, the crystal crop produced with isopropyl alcohol slurries appeared more rapidly than crystal crops produced with oil slurries.

Although crystal crops obtained with oil slurries were more irregular than those obtained with isopropyl alcohol slurries, the molasses purities, low-grade sugar purities, purging times, and other characteristics of the finished massecuites were not appreciably different, indicating that the small differences in crystal crop regularity had little practical significance. This point is of some importance since, if these slurries should be prepared at Crockett, the white oil would probably be preferred as a vehicle because of the better storage qualities of the oil slurries. Both the water content and the volatility of the alcohol seem to have an adverse effect on the stability of the alcohol slurries. A further point of consideration is the fire hazard involved in the use of the alcohol, which is inflammable.

The previously mentioned point of lessened Fondant sugar requirements when using non-aqueous vehicles was very apparent in these tests, the amount of Fondant sugar required being about 1/10 that usually required with a saturated sugar liquor slurry. One pound of Fondant sugar will produce approximately 2000 cubic feet of massecuite which will leave the crystallizer with an average crystal size of 0.3 mm. However, the maximum and minimum amount of massecuite produced varied from 1100 to 2500 cubic feet per pound of Fondant sugar. The amount of Fondant sugar required appears to vary with pan designs and possibly with the quality of the boiling material.

Tests were also conducted on two different seeding operations to determine whether grain was being shocked into the seed strikes by the use of non-aqueous vehicles thereby producing the additional unexpected seed. In each case, the boiling material was brought to the graining point (which was determined as usual), then 1½ gallons of No. 3 white oil without Fondant sugar added were injected into the pan and the graining charge was observed for the possible appearance of shocked grain. The observation period extended through the normal 30-minute rest period during which time the mechanical circulator was on, the calandria steam off, and

the vacuum constant. No grain appeared in either tests; therefore, it was concluded that shocking in of grain by use of non-aqueous vehicles does not take place at supersaturation values associated with the normal seeding point.

Some question has arisen as to why aqueous and non-aqueous Fondant slurries with equal amounts of Fondant sugar produce such widely different quantities of grain under similar pan graining procedures. This difference is undoubtedly related to the solubility characteristics of various sized sugar crystals in aqueous sugar solutions. Theoretically, the finer sugar particles have a slightly greater solubility than the larger grain, with the result that they tend to dissolve even in solutions which are saturated. From a practical standpoint, many of the numerous sub-microscopic Fondant particles in a saturated sugar liquor are dissolved before the slurry can be injected into the pan. On the other hand, the sub-microscopic Fondant seed nuclei will not be destroyed by a non-aqueous vehicle and, therefore, will exist as stable nuclei, capable of growth in the range of supersaturations encountered in the graining procedure.

SEED

PREPARATION The one noteworthy advantage of non-aqueous Fondant slurries over aqueous Fondant slurries is the ease of preparation with full assurance that there will be no loss of Fondant seed due to the vehicle. The low Fondant seed requirement, .05 pound per 100 cubic feet of massecuite, necessitates the use of only a very small amount of vehicle for a 2000-cubic-foot strike. To satisfactorily disperse one pound of Fondant seed and produce a slurry with sufficient fluidity for injection through seed cups, it was found necessary to use 1½ quarts of non-aqueous vehicle.

A mixing tank of about two or three gallons capacity connected to the seed inlet pipe of the pan through a suitable connection equipped with a quick opening valve may be used for preparation of the slurry. A Lightning type stirrer (1/8 or 1/30 h.p.) is used for intensive mixing of the slurry ingredients. The Fondant sugar should be slowly added to the agitated vehicle to prevent lump formation in the slurry. Adequate time for intensive mixing of the slurry should be allowed in order to assure complete dispersion of the seed nuclei; 15 minutes was found to be satisfactory. The slurry should be agitated vigorously by shaking or by using the mixer just prior to introduction into the pan.

Section 4.

MECHANICAL CIRCULATION VS. STEAM AGITATION

1. Mechanical Circulator Installation

It has been our experience that adaptation of the improved boiling technique for seed strikes is not possible without a means for producing a certain amount of massecuite circulation, independent of the natural circulation induced by the calandria. In practice, this means that the seed pan must be equipped either with a mechanical circulator or with adequate steam agitation coils suitably located under the calandria. Since a choice of one or the other type of installation must be made if the proposed pan technique is to be successfully employed, a brief outline of the advantages and disadvantages of each may be of interest.

The boiling tests at the raw factories have definitely proved that forced mechanical circulation in calandria pans permits the use of a very simple and dependable pattern of pan manipulation for controlling supersaturation during the initial grain growth period. All that is necessary is to shut off steam periodically to prevent the otherwise natural rise in supersaturation. The required circulation is adequately maintained during these non-boiling intervals by the mechanical circulator.

Since effective control of supersaturation is essential to good results, this advantage of simplicity and dependability of control assumes considerable importance.

A second important advantage of the circulator installation is that it permits the desirable practice of stopping all ebullition immediately after introduction of seed. Adequate circulation can be maintained by the circulator alone. Since ebullition is unnecessary to maintain massecuite movement with the circulator, the melting out of an unpredictable amount of fine seed, which otherwise occurs, is avoided. The net result is that the pan manipulative technique made possible by the circulator assures exact control over the amount of seed established. This is a very important element in consistently obtaining the best molasses exhaustion.

Another advantage of the mechanical circulator is that the ammeter on the drive motor may be used either to indicate, record or control the massecuite consistency. Inasmuch as it has been found beneficial to boil the strike "close" or "stiff," this feature has proved also of considerable value in obtaining consistently good results. If manual feed control is used, the pan man can readily make necessary adjustments to hold the motor load at the level that gives the desired consistency. By means of a contact-making ammeter connected to a suitable motor or air-operated feed valve, the feed and massecuite consistency may be controlled automatically, exactly as desired.

Still another important advantage, which has been fully established by earlier studies of mechanical circulators, is the improvement in pan circulation achieved by the circulator during the latter half of the strike, when natural circulation becomes sluggish. This produces certain specific benefits as follows:

- The massecuite crystal crop is of better quality as indicated by the presence of less fines and conglomerates, and a more uniform grain size.
- Boiling rate is increased in the latter stages of the strike, thus increasing pan capacity.
- Pan purity drops are improved, for any given boiling time.

A fifth and important advantage of the mechanical circulator relates to the opportunity it affords to control precisely the consistency of the massecuite at time of striking. Studies conducted by the HSPA Experiment Station have proved that, for best molasses exhaustion work, the density of a final massecuite should be as high as practical considerations of viscosity and massecuite fluidity will permit. In "boiling down" a massecuite, human judgment of massecuite consistency is ordinarily relied upon to determine when the strike should be dropped. By its very nature, such judgment cannot be expected to be consistent—and in fact it frequently errs. However, by means of the circulator, the massecuite fluidity can readily be determined by observing the mechanical circulator drive motor load. All that is necessary to consistently produce a massecuite of maximum safe density is to establish the corresponding load requirement of the circulator drive motor. Such a control should definitely contribute towards improved average molasses exhaustion.

The bulk of the test strikes produced during the experimental period were boiled in Oahu Sugar Company pans, all of which are equipped with mechanical circulators that have three rotor elements. It is not known whether the upper rotors are of value, since comparative tests with a single rotor installation were not made. If the level of the final massecuite is carried higher than six feet above the top tube sheet, additional rotors then may be of a certain amount of value. At lower massecuite levels, however, it is our general opinion that a single rotor circulator of good engineering design is sufficient for the intended purpose.

Either the Smith or Webre type mechanical circulator should prove adequate for the needs of the improved technique, provided, of course, that rotor speeds are sufficient to produce the necessary circulation. However, possible failure, or an unnecessary development expense may result from attempts to use circulators of a design that has not been tried and proved.

The main objection to the mechanical circulator appears to be its higher cost, compared to the alternate plan of providing steam agitation coils. The increase in factory power load should also be mentioned as a possible objection. Some added maintenance cost is also involved; however, this is very minor in relative magnitude. Although the comparative investment costs merit full consideration, the difference in the degree of molasses exhaustion improvement that can be expected from the two types of installations may prove to be a factor of greater influence than investment in arriving at a final decision. Most of the points of superiority inherent to the circulator installation have a direct bearing on better molasses exhaustion. Of course, either installation should effect a saving of \$1 or more per ton of raws produced, if their use is coupled with the improved low-grade boiling technique suggested.

There is little doubt but that a greater improvement in molasses exhaustion will be secured with the mechanical circulator installation than with the steam coil installation. Just how much this improvement will be is not known. In the writers' opinion, however, it is quite conceivable that it may amount to as much as 30 cents per ton of raws—possibly even more. In the case of factories that produce 50,000 tons or more raws per year, such an incremental improvement should pay for the difference in cost between the two types of installations in much less than a year. Under such conditions, the circulator installation would appear to be the best investment. In the case of small factories, however, the return on the investment difference obviously would be much smaller because of smaller outputs, and the circulator installation would naturally be less attractive.

In arriving at a final decision as to which type of installation is to be selected for permanent work, it may be helpful to give consideration to these various elements.

2. Steam Agitation

As an alternate, but less satisfactory method of augmenting natural circulation, a calandria may be equipped with two perforated steam agitation coils, which are supplied with steam independently of the calandria. A reasonably satisfactory technique of pan manipulation has been developed for use with such installation. This plan is designed to control supersaturation within safe limits and, at the same time, maintain sufficient circulation to produce a reasonably good strike. However, the technique is not as practical and "fool proof" for factory work as the method used with the mechanical circulator installation.

Ebullition resulting either from the calandria or open steam injection is not a

desirable condition during the very early part of the strike, because it tends to melt out an undetermined fraction of the very small seed grain. It must be accepted, however, as the lesser of two evils, for still more objectionable changes in the quality of the grain crop will develop when no circulation exists. The ultimate result, therefore, is that strikes boiled with the steam coil technique have greater variation in final crystal concentration and this in turn adversely affects molasses exhaustion.

The principal advantage of the steam agitation coil over the mechanical circulator installation is its relatively low initial cost.

The cost of the coil installation itself is small compared to the mechanical circulator. However, in addition to the coils, an extra control instrument that will regulate the vacuum variation cycle must be provided. Furthermore, if the seed pan has a deep conical bottom, it probably will have to be replaced by a streamline bottom, if a worth-while improvement in results is to be obtained. Also, the technique used with the steam coil, even when all these provisions have been made, does not produce consistently as good results with respect to molasses exhaustion and sugar quality as the simple technique possible with the circulator.

When the lesser financial gain (compared to the circulator technique) possible with the steam agitation method is considered, and the resulting loss equivalent (extending over—say a year) is added to the investment for coils, instrument and pan bottom, the total may exceed the installed cost of the circulator. For a permanent installation, therefore, the advantage of cheapness of the coil installation may prove to be a misconception when careful consideration is given all the factors involved.

Section 5.

DESUGARIZING POTENTIAL CORRELATIONS

The effect of reduced crystal yield on the Desugarizing Potential of the masse-cuite may be illustrated by calculating the decreased aggregate crystal surface area available per unit of dissolved solids as the percentage crystal yield is decreased. For this calculation, assume that the crystal size is 0.295 mm and that, accordingly, the crystal surface is 13.5 mm² per milligram of crystal. (See Table II, page 28, E. C. Gillett's report, "Low-Grade Sugar Crystallization".) This surface area is equivalent to

$$\frac{13.5 \times 1000 \times 453.6}{10^3 \times 2.54^2 \times 12^2} = 66.0 \text{ sq. ft. per lb. of crystal.}$$

On this basis, the decreased Desugarizing Potentials shown in Table XIII, may be calculated.

Table XIII

% Crystal Yield by Weight	% Mother Liquor Solids by Weight	Crystal Surface Area Sq. Ft. per Lb. of M. L. Solids (Relative Desugarizing Potential)	Decrease in Surface Area (Sq. Ft.) Per Lb. of M. L. Solids per Unit Change in % Crystal Yield	Desugarizing Potential as of % of Potential at 47% Crystal Yield
47.0	53.0	58.6	...	100
46.0	54.0	56.2	2.4	96
45.0	55.0	54.0	2.2	92
44.0	56.0	51.8	2.2	89
43.0	57.0	49.7	2.1	85

From the table, it is evident that each unit decrease in percentage crystal yield results in a loss of crystal surface amounting to about 2.2 square feet per pound of mother liquor solids.

This decrease in Desugarizing Potential may be placed on another basis, i.e., the equivalent change in crystal size to produce the same loss in surface area without change in crystal yield. For instance, consider the surface areas of the crystal of these two sizes:

Mesh	Size—mm	Surface—mm ² /mg
42	0.351	11.4
48	0.295	13.5
<hr/>		<hr/>
Differences	0.056	— 2.1

The percentage decrease in area resulting from an increase in crystal size from 0.295 to 0.351 mm is

$$\frac{13.5 - 11.4}{13.5} \times 100\% = 15.5\%$$

However, the percentage decrease in area per pound of mother liquor solids, resulting from 1 per cent decrease in crystal yield is only

$$\frac{2.2}{58.6} \times 100\% = 3.8\%$$

Assuming a linear relationship for the small interval—the increase in crystal size to effect the same reduction in crystal area would be:

$$\frac{3.8}{15.5} \times 0.056 = 0.014 \text{ mm}$$

Or, an increase in linear size of the crystal from 0.295 mm to 0.309 mm, with constant crystal yield, would result in the same reduction in Desugarizing Potential as a decrease of 1 per cent in crystal yield, with constant crystal size.

Section 6.

CALCULATIONS OF DESUGARIZING POTENTIAL FROM YIELD

Desugarization Potential is proportional to the ratio of crystal surface area to mother liquor solids. Calculations of relative Desugarization Potentials on this basis require knowledge of crystal size as well as crystal yield data. However, if constant crystal size is assumed, these relative potentials may be calculated directly from percentage crystal yield.

Three methods have been employed to calculate the relative Desugarization Potentials based on the ratio of crystals to mother liquor in a massecuite as the percentage crystal yield increases.

For illustration, calculations will be described in detail for crystal yields of 38.6 and 39.4 per cent.

Method I—Direct Weight Ratios

For a massecuite of 38.6 per cent crystal yield, the ratio of crystals to mother liquor is

$$\frac{38.6}{100-38.6}=0.629$$

For the massecuite with 39.4 per cent crystal yield, the ratio is

$$\frac{39.4}{100-39.4}=0.650$$

The increase in the crystal-mother liquor ratio, or Desugarization Potential, as the crystal yield increases from 38.6 to 39.4 per cent is

$$\frac{0.650-0.629}{0.629} \times 100\% = 3.3\%$$

Method II—Approximate Volume Ratios

In E. C. Gillett's report, "Low-Grade Sugar Crystallization," it was shown that a massecuite which had 44 per cent crystals by volume, had 49 per cent crystals by weight. That is

$$\frac{\% \text{ crystals by vol. } 44}{\% \text{ crystals by wt. } 49} = 0.899$$

Volume ratios may be calculated from percentage crystal yield by using this factor, as follows:

Percentage crystals by volume in massecuite with 38.6 per cent crystal yield is
 $38.6 \times 0.899 = 34.7\%$

Ratio of crystals to mother liquor, by volume, for this massecuite is

$$\frac{34.7}{100-34.7}=0.531$$

Similarly,

Percentage crystals by volume for a massecuite with 39.4 per cent crystal yield is
 $39.4 \times 0.899 = 35.4\%$

and volume ratio of crystals to mother liquor for this massecuite is

$$\frac{35.4}{100-35.4}=0.548\%$$

Then, the increase in ratio of crystals to mother liquor (relative Desugarizing Potential) caused by an increase from 38.6 to 39.4 per cent in crystal yield is

$$\frac{0.548-0.531}{0.531} \times 100\% = 3.2\%$$

Method III—True Volume Ratios

Assume: specific gravity of crystals	=	1.59
specific gravity of mother liquor	=	1.479
mother liquor density	=	88.4 RDS

For massecuites with 38.6% crystal yield:

% crystals by weight	=	38.6
% mother liquor solids by weight	=	61.4

$$\begin{array}{rcl}
 \text{Volume of crystals} & = & \frac{38.6}{1.59} = 24.3 \\
 \text{Volume of mother liquor} & = & \frac{61.4}{0.884 \times 1.479} = 47.0 \\
 \text{Total volume} & & = 71.3 \\
 \% \text{ crystals by volume} & = & \frac{24.3}{71.3} \times 100\% = 34.1\% \\
 \text{Ratio of crystals to mother} & & \\
 \text{liquor by volume} & = & \frac{34.1}{100 - 34.1} = 0.517
 \end{array}$$

For massecuite with 39.4% crystal yield:

$$\begin{array}{rcl}
 \% \text{ crystals by weight} & = & 39.4 \\
 \% \text{ mother liquor solids by} & & \\
 \text{weight} & = & 60.6 \\
 \text{Volume of crystals} & = & \frac{39.4}{1.59} = 24.8 \\
 \text{Volume of mother liquor} & = & \frac{60.6}{0.884 \times 1.479} = 46.4 \\
 \text{Total volume} & & = 71.2 \\
 \% \text{ crystals by volume} & = & \frac{24.8}{71.2} = 34.8 \\
 \text{Ratio of crystals to mother} & & \\
 \text{liquor, by volume} & = & \frac{34.8}{100 - 34.8} = 0.534
 \end{array}$$

Then, the increase in ratio of crystals to mother liquor (relative Desugarizing Potential) caused by an increase in crystal yield from 38.6% to 39.4% is

$$\frac{0.534 - 0.517}{0.517} \times 100\% = 3.3\%$$

Methods:

- I. Based on direct ratio of $\frac{\% \text{ crystal yield by weight}}{\% \text{ mother liquor by weight}}$
- II. Based on ratio of $\frac{\text{Approx. } \% \text{ crystal by volume}}{\text{Approx. } \% \text{ mother liquor by volume}}$,
 where approx. $\% \text{ crystals by volume} = \frac{44}{49} \times \% \text{ crystal yield} = 0.899 \times \% \text{ of crystal yield}$.

Table XIV
Effect of Percentage Crystal Yield on Desugarizing Potential—
Summary of Three Methods of Calculation

Percentage Crystal Yield on Massecuite Solids by Weight	Increase in Relative Desugarizing Potential		
	Method I	Method II	Method III
38.6	Basis	Basis	Basis
39.4	3.3	3.2	3.3
41.9	14.6	13.9	15.1
43.6	22.9	21.5	23.2
43.8	23.8	22.4	23.6
44.1	25.4	23.5	25.7
44.2	25.9	23.9	25.7
46.2	36.6	33.5	37.1
46.7	39.3	36.3	39.4
51.4	68.2	61.8	68.1

III. Based on ratio of

$\frac{\% \text{ crystal by volume}}{\% \text{ mother liquor by volume}}$

$\frac{\text{specific gravity of crystals}}{\text{specific gravity of mother liquor}}$

$\frac{\text{mother liquor density}}{\text{RDS}} = 1.59$

$\frac{\text{specific gravity of mother liquor}}{\text{RDS}} = 1.479$

$\frac{\text{mother liquor density}}{\text{RDS}} = 88.4$ RDS

Section 7.

CALCULATION OF CHANGES IN MASSECUITE CHARACTERISTICS DURING CURING (See Table 7)

Data:

Massecuite Purity	61.6° AP
Pan Purity Drop	19.9° AP
Crystallizer Purity Drop	13.1° AP
Measured Shrinkage after Curing	20.0%
Crystal Size when Leaving Pan	0.27 mm
Mother Liquor Density Leaving Pan	92.0 RDS
Sugar Crystal Purity	99.0° AP
Expected Molasses Purity	29.54° Suc./RDS
Actual Molasses Purity	34.47° Suc./RDS

1. Yield of Sugar Crystals Leaving Pan

Massecuite Purity 61.6°

Sugar Purity 99.0°

Mother Liquor Purity 61.6 - 19.9 = 41.7°

$$\text{Yield} = \frac{61.6 - 41.7}{99.0 - 41.7} \times 100\%$$

$$= \frac{19.9}{57.3} \times 100\% = 34.8\% \text{ crystal solids on massecuite solids.}$$

Table XV
Detailed Tabulation of Data Used in Summary of Effect of Crystal Yield
On Relative Desugarizing Potential

% Crystal Yield on Masecuite Solids by Weight	Ratio of Crystal Solids to Mother Liquor Solids by Weight	% Increase in Ratio	% Crystal on Mass. Volume (% Crystal Yield x 0.899)	Ratio of Crystal Volume to Mother Liquor Volume	% Increase in Ratio	% Crystal Vol. on Mass. Vol. Using Specific Gravities	Ratio of Crystal Vol. to Mother Liquor Volume	% Increase in Ratio
38.6	0.629	....	34.7	0.531	....	34.1	0.517	....
39.4	0.650	3.3	35.4	0.548	3.2	34.8	0.534	3.3
41.9	0.721	14.6	37.7	0.605	13.9	37.3	0.595	15.1
43.6	0.773	22.9	39.2	0.645	21.5	38.9	0.637	23.2
43.8	0.779	23.8	39.4	0.650	22.4	39.0	0.639	23.6
44.1	0.789	25.4	39.6	0.656	23.5	39.4	0.650	25.7
44.2	0.792	25.9	39.7	0.658	23.9	39.4	0.650	25.7
46.2	0.859	36.6	41.5	0.709	33.5	41.5	0.709	37.1
46.7	0.876	39.3	42.0	0.724	36.3	41.9	0.721	39.4
51.4	1.058	68.2	46.2	0.859	61.8	46.5	0.869	68.1
Specific gravities:								
Crystals..... 1.59								
Mother liquor..... 1.479								
Mother liquor density.... 88.4 RDS.								

2. Yield of Sugar Crystals Leaving Crystallizer

Massecuite Purity	61.6°
Sugar Purity	99.0°
Mother Liquor Purity	$61.6 - 19.9 - 13.1 = 28.6°$

$$\begin{aligned} \text{Yield} &= \frac{61.6 - 28.6}{99.0 - 28.6} \times 100\% \\ &= \frac{33.0}{70.4} \times 100\% = 46.9\% \text{ crystal solids on massecuite solids} \end{aligned}$$

3. Decrease in Density of Mother Liquor

Density of mother liquor leaving pan	92.0
From 100 lbs. of massecuite solids, crystal yield leaving pan	34.8 lbs.
From 100 lbs. of massecuite solids, crystal yield leaving crystallizer	46.9 lbs.
Molasses solids leaving pan $100 - 34.8 =$	65.2 lbs.
Water in molasses leaving pan $65.2 \times \frac{8}{92} =$	5.67 lbs.
Molasses solids leaving crystallizer $100 - 46.9 =$	53.1 lbs.
Molasses density leaving crystallizer $\frac{53.1}{53.1 + 5.67} \times 100\% =$	90.35%

4. Crystal Size Leaving Crystallizer

Crystal size leaving pan	0.27 mm
Crystal yield leaving pan, from 100 lbs. massecuite	34.8 lbs.
Crystal yield leaving crystallizer, from 100 lbs. massecuite	46.9 lbs.

$$\text{Per cent gain in crystal weight} = \frac{46.9 - 34.8}{34.8} \times 100\% = 34.8\%$$

(Length of crystal is proportional to cube root of its weight.)

$$\begin{aligned} \therefore \text{Length of crystal leaving crystallizer} &= 0.27 \frac{(1.348)^{\frac{1}{3}}}{(1.000)} \\ &= 0.27(1.105) \\ &= 0.30 \text{ mm} \end{aligned}$$

5. Shrinkage Leaving Pan

Density of Mother Liquor leaving pan	92.0%
Crystal yield leaving pan	34.8%

A laboratory determination of specific gravity of an 88.4 RDS (1+5 dilution) Hawaiian molasses, indicated that 0.0076 should be added to sucrose specific gravities from tables to give molasses specific gravities. This correction is applied to the molasses specific gravities considered herein.

Then,	
Specific gravity of mother liquor	$\frac{(20)}{(20)}$
	$1.4967 + 0.0076 =$
	1.5043
Specific gravity of crystals	1.59
In 100 lbs. of massecuite solids, volume of crystals	
	$\frac{100 \times .348}{1.59 \times 62.3} =$
	0.351 cu. ft.
Volume of mother liquor	$= \frac{100 (1.00 - .348)}{1.504 \times 62.3} \times \frac{100}{92} =$
	0.756 cu. ft.
Total volume =	1.107 cu. ft.

Assume that pore space in compact crystal bed is 47%,

Mother liquor required to fill pore space	
	$= 0.351 \times \frac{47}{53} =$
	0.311 cu. ft.
Excess mother liquor $0.756 - 0.311 =$	0.445 cu. ft.
Shrinkage	$= \frac{0.445}{1.107} \times 100\% =$
	40.2%

6. Shrinkage Leaving Crystallizer

Density of mother liquor leaving crystallizer	90.35%
Specific gravity of mother liquor leaving crystallizer	
	$= 1.4851 + .0076 =$
	1.4927
Crystal yield leaving crystallizer	46.9%
In 100 lbs. of massecuite solids, volume of crystals	
	$\frac{100 \times .469}{1.59 \times 62.3} =$
	0.473 cu. ft.
Volume of mother liquor	$= \frac{100 (1.00 - .469)}{1.493 \times 62.3} \times \frac{100}{90.35} =$
	0.632 cu. ft.
Total Volume	1.105 cu. ft.
Mother liquor to fill pores	$0.473 \times \frac{47}{53} =$
	0.420 cu. ft.
% Shrinkage	$= \frac{0.632 - 0.420}{1.105} \times 100\% =$
	19.2%

7. Assume Final Purity is 2 points below that in above example

Final mother liquor purity	$= 28.6 - 2.0 =$
	26.6°

a. Crystal Yield

$$\text{Yield} = \frac{61.6 - 26.6}{99.0 - 26.6} \times 100\% = 48.3\% \text{ crystal solids on massecuite solids}$$

b. Decrease in Mother Liquor Density

Solids in mother liquor from 100 lbs. of massecuite

$$100 - 48.3 = 51.7$$

Water in massecuite 5.67

$$\text{Mother liquor density} = \frac{51.7}{51.7 + 5.67} = 90.12 \text{ RDS}$$

c. Crystal Size

Crystal size leaving pan 0.27 mm

Crystal yield leaving pan from 100 lbs. massecuite 34.8 lbs.

Crystal yield at lowered molasses purity 48.3

$$\text{Per cent gain in crystal weight} = \frac{48.3 - 34.8}{34.8} = 38.8\%$$

$$\begin{aligned} \text{Length of crystal} &= 0.27 \frac{(1.388)^{1/3}}{(1.000)} \\ &= 0.27 (1.115) = 0.30 \text{ mm} \end{aligned}$$

d. ShrinkageSpecific gravity of mother liquor = $1.4834 + .0076 = 1.4910$

In 100 lbs. of massecuite solids

$$\text{Volume of crystals} = \frac{100 (.483)}{1.59 \times 62.3} = .487 \text{ cu. ft.}$$

$$\text{Volume of mother liquor} = \frac{100 (1.00 - .483)}{1.4910 \times 62.3} \times \frac{100}{90.12} = 0.617 \text{ cu. ft.}$$

Total volume 1.104 cu. ft.

$$\text{Mother liquor to fill pores} = 0.487 \times \frac{47}{53} = 0.432$$

$$\% \text{ Shrinkage} = \frac{.617 - .432}{1.104} \times 100\% = 16.7\%$$

8. Calculated Measured Shrinkages

Assume ratio of measured to calculated shrinkages is constant

Measured shrinkage leaving crystallizer is 20 %

Calculated shrinkage leaving crystallizer is 19.2 %

On this basis other measured shrinkages would be:

$$\text{Leaving pan} \quad 40.2 \times \frac{20}{19.2} = 41.9\%$$

$$\text{With 2° additional purity drop} \quad 16.7 \times \frac{20}{19.2} = 17.4\%$$

9. Calculated Points Above Expected Purity

Expected Purity—Sucrose/RDS	29.54°
Actual molasses purity—Sucrose/RDS	34.47°
—AP	28.6°

Difference between Sucrose/RDS and AP for 28.6° AP molasses
 $= 34.47 - 28.6 = 5.87$ points

Assume this difference is proportional to per cent impurity on AP basis.
 Then, the difference for the mother liquor leaving pan (41.7° AP) is

$$5.87 \times \frac{100 - 41.7}{100 - 28.6} = 4.8 \text{ points.}$$

For molasses of 26.6 AP, this difference is

$$5.87 \times \frac{100 - 26.6}{100 - 28.6} = 6.0 \text{ points}$$

From these data, the points above Expected Purity for the mother liquor under each situation considered, may be calculated, as follows:

	Leaving Pan	Leaving Cryst.	2 Points Lower
Mother liquor AP.....	41.7°	28.6°	26.6°
Difference Sucrose/RDS purity—AP.....	4.8	5.87	6.0
Mother liquor—Sucrose/RDS purity.....	46.5	34.47	32.6
Points above Expected Purity (29.54°).....	17.0	4.93	3.1

Section 8.

DATA SHEETS

Table XVI

Data For Figure 3

Effect of Crystal Yield on Molasses Exhaustion Potential

% Crystal Yield on Masseccuite Solids	% Increase in Molasses Exhaustion Potential
38.6	0
39.4	3.3
41.9	14.6
43.6	22.9
43.8	23.8
44.1	25.4
44.2	25.9
46.2	36.6
46.7	39.3
51.4	68.2

Table XVII
Data for Figures 4 and 5
Effect of Crystal Yield on Molasses Purity
(A) Points Above Expected Purity and (B) Total Purity Drop

Mass. AP $60.4^{\circ} \pm 1.0^{\circ}$					
Mass. AP	Crystal Yield on Mass. Solids	Total Points Purity Drop	Points Above Expected Purity	RS/A Ratio	Cryst. Hours
	%	AP			
60.4	43.6	29.8	6.07	1.79	35
60.0	43.8	30.4	6.32	1.75	34
61.4	46.2	32.3	5.33	1.72	33
59.4	41.9	28.5	6.93	1.74	36
59.8	42.6	29.1	6.47	1.88	84
60.5	45.4	32.1	5.07	1.97	78
60.5	46.5	33.4	4.00	1.98	80
61.2	45.8	31.9	4.98	2.03	60
Mass. AP $58.5^{\circ} \pm 1.2^{\circ}$					
58.1	38.6	25.7	7.43	1.91	32
58.6	39.4	26.6	7.27	1.87	36
59.7	44.2	31.0	4.65	1.85	29
58.3	42.6	30.2	5.43	1.69	90
58.9	44.6	31.3	4.06	1.73	83
57.4	41.6	29.6	4.76	1.72	84

Table XVIII
Data for Figure 7
Massecuite Purities To Give 45% Yield of 99° Purity Crystals

D=3	J=0.55M+44.55	M=EP+3-A			
		Objective Expected Purity (EP+3)			
		Calculated Massecuite Purity (AP)			
Expected Purity (EP) Sucrose-Rds.		A=5	A=6	A=7	
24°	27°	56.65°	56.10°	55.55°	
25	28	57.20	56.65	56.10	
26	29	57.75	57.20	56.65	
27	30	58.30	57.75	57.20	
28	31	58.85	58.30	57.75	
29	32	59.40	58.85	58.30	
30	33	59.95	59.40	58.85	
31	34	60.50	59.95	59.40	
32	35	61.05	60.50	59.95	
33	36	61.60	61.05	60.50	
34	37	62.15	61.60	61.05	
35	38	62.70	62.15	61.60	

Table XIX
Data for Figure 8
Massecuite Purities To Give 43% Yield of 99° Purity Crystals

D=3	J = 0.57M + 42.57	Objective Expected Purity (EP+3)	M = EP + 3 - A		
			Calculated Massecuite Purity (AP)		
			A = 5	A = 6	A = 7
	Expected Purity (EP) Sucrose-Rds.				
	24°	27°	55.11°	54.54°	53.97°
	25	28	55.68	55.11	54.54
	26	29	56.25	55.68	55.11
	27	30	56.82	56.25	55.68
	28	31	57.39	56.82	56.25
	29	32	57.96	57.39	56.82
	30	33	58.53	57.96	57.39
	31	34	59.10	58.53	57.96
	32	35	59.67	59.10	58.53
	33	36	60.24	59.67	59.10
	34	37	60.81	60.24	59.67
	35	38	61.38	60.81	60.24

Table XX
Data for Figures 12 and 13
Relation of Total % Purity Drop to (A) Pan Crystal Yield and
(B) to Massecuite Purity, for Two Different Curing Periods

Massecuite Purity-AP	Final Molasses Ref. Suc. Pur. (Actual & Expected)	Total Points Purity Drop (Actual & Expected)	Actual Purity Drop as % of Expected	Pan- Per cent Crystal Yield on Mass. Solids
34 Crystallizer Hours				
60.4°	36.1° Actual	24.3	79.9	32.8
60.4	30.0 Expected	30.4		
60.0	36.5° Actual	23.5	78.8	31.5
60.0	30.2 Expected	29.8		
61.4	35.7 Actual	25.7	82.6	35.3
61.4	30.3 Expected	31.1		
59.4	37.2 Actual	22.2	76.0	31.3
59.4	30.2 Expected	29.2		
58.1	37.0 Actual	21.1	74.0	28.2
58.1	29.6 Expected	28.5		
58.6	37.0 Actual	21.6	74.7	28.4
58.6	29.7 Expected	28.9		
59.7	34.4 Actual	25.3	84.6	32.5
59.7	29.8 Expected	29.9		

Table XXI
Data for Figures 12 and 13 (Continued)

Masseccuite Purity-AP	Final Molasses Ref. Suc. Pur. (Actual & Expected)	Total Points Purity Drop (Actual & Expected)	Actual Purity Drop as % of Expected	Pan- Per cent Crystal Yield on Mass. Solids
80 Crystallizer Hours				
58.3°	35.9° Actual	22.4	81.5	31.6
58.3	30.8 Expected	27.5		
58.9	34.3 Actual	24.6	86.0	34.0
58.9	30.3 Expected	28.6		
57.4	35.1 Actual	22.3	82.3	28.4
57.4	30.3 Expected	27.1		
59.8	36.1 Actual	23.7	78.7	34.3
59.8	29.7 Expected	30.1		
60.5	34.4 Actual	26.1	83.7	34.8
60.5	29.3 Expected	31.2		
60.5	33.3 Actual	27.2	87.2	35.8
60.5	29.3 Expected	31.2		
61.2	34.1 Actual	27.1	84.4	31.2
61.2	29.1 Expected	32.1		

Table XXII
Data for Figure 14
Theoretical Relationship of Crystal Yield and Final Molasses Purity
at Constant Masseccuite Purity

Masseccuite Purity - AP	Molasses Purities - AP					
	49% Crystal Yield	47% Crystal Yield	45% Crystal Yield	43% Crystal Yield	41% Crystal Yield	39% Crystal Yield
56°	14.7°	17.9°	20.8°	23.6°	26.1°	28.5°
58	18.6	21.6	24.5	27.1	29.5	31.8
60	22.5	25.4	28.1	30.6	32.9	35.1
62	26.5	29.2	31.7	34.1	36.3	38.3
64	30.4	33.0	35.4	37.6	39.7	41.6

Table XXIII—Experiments on Improved Low-Grade Pan

Test No.	Pan & Strike No.	Date	Hours Boiling	Finishing Temp. °F.	Vol. Cu. Ft.	Graining Charge Data								Mass. Temp. °F.	Massecuite Leaving Pan							
						Material	Ap. Pur.	Ref. Brix	Vol. Cu. Ft.	Seed Lbs.	Vac. In.	B. P. Elev.	Temp. °F.		Ref. Brix	Ap. Pur.	M. Liquor		Pan Pur. Drop	Pan Rotor Amps.	Shrinkage	
																	Brix	Pur.			%	Hrs.
23	739	9/3/48	6	..	900	Remelt & A-Mol.	71.3	..	450	6	25.5	25.0	..	...	95.9	54.5	...	40.5	14.0	..	..	..
23-A	740	9/3/48	7¾	..	900	Cut								...	95.1	58.9	...	41.0	17.9	..	..	..
23-B	741	9/3/48	4½	..	900	Cut								...	96.3	58.7	...	40.7	18.0	..	..	..

Table XXIV—Experiments on Improved Low-Grade Pan

12	VIII	8/18/48	7½	..	1600	Remelt & Syrup	74.8	..	650	12	25.8	...	151.5	...	92.9	67.7	...	...	...	...	...	...
13	VIII	8/19/48	10	..	1200	Remelt & Syrup	83.2	..	650	12	25.0	22	156	...	94.3	64.9	92.6	55.0	9.9	..	19	..
13-A	V	8/19/48	9½	..	1100	Remelt & Syrup	74.2	..	700	8	26.0	...	...	...	93.5	66.5	91.6	50.7	15.8	..	..	..
14	VIII	8/20/48	2200									...	94.4	64.0	93.4	53.4	10.6
15	VII	8/21/48	..	..	4000	Remelt & Syrup	73.3	88.1	720	12	26.0	...	...	...	94.7	63.4	93.2	54.3	9.1	..	..	..

Table XXV—Experiments on Improved Low-Grade Pan

16	V-332	8/25/48	17 $\frac{1}{2}$	172	1625	Remelt & A-Mol.	64.1	...	450	8	25.8	25	154	172	96.8	57.0	...	...	...	..	..	..
17	V-334	8/26/48	19	..	1625	Remelt & A-Mol.	73.2	...	450	8	25.8	23	...	...	98.6	55.9	...	...	...	..	..	..
18	336	8/27/48	13	..	3250	Remelt & A-Mol.	72.2	...	450	8	25.8	23.5	...	175	97.1	57.3	...	...	...	..	22	..

Table XXVI—Experiments on Improved Low-Grade Pan

1	III-369	7/28/48	11	180	1500	B-Mol.	64.8	88.2	720	8	25.8	24.5	155.5	180	94.6	62.2	90.1	40.3	22.3	45	16	..
1-A	II-370	7/28/48	9½	164	1500	Cut							164	95.1	57.9	89.7	39.2	18.7	30	29	6	..
2	III-372	7/29/48	7¼	176	1500	B-Mol.	67.3	89.0	540	6	25.9	22	152	176	96.7	63.4	91.7	42.3	21.1	40	25	..
3	III-381	8/2/48	9½	174	1500	" "	66.7	87.7	650	7	25.6	22.5	154	174	95.2	61.2	92.3	44.1	17.1	35	17	17
3-A	II-382	8/2/48	10½	162	1500	Cut							162	96.9	60.1	91.3	42.1	18.0	35	21	11	..
4	III-384	8/3/48	5½	167	1500	B-Mol.	64.8	87.8	750	6	26.0	24.5	154	167	95.4	65.4	91.0	46.8	18.6	42	17	17
5	III-392	8/5/48	9½	170	1500	Remelt Sugar	78.9	87.1	720	8	...	21.5	152.5	170	95.3	62.4	92.3	44.1	18.3	40	22	12
5-A	II-393	8/5/48	11¾	160	1500	Cut							160	94.1	61.4	90.8	41.0	20.4	40	26	16	..
6	III-394	8/6/48	10	175	1500	Remelt & Mol.	71.7	84.5	720	8	25.6	20.0	151.5	175	95.0	63.3	91.7	40.2	23.1	45	17	17
6-A	II-395	8/6/48	10	160	1500	Cut							160	95.4	63.1	89.6	42.1	21.0	30	25	12	..
7	III-400	8/9/48	11	170	1500	Remelt & Mol.	76.7	83.3	720	8	...	18.0	147	170	95.8	61.9	91.9	40.1	21.8	43	..	..
7-A	II-401	8/9/48	9	162	1500	Cut							162	96.2	62.4	91.6	43.2	19.2	30	..	..	..
8	III-403	8/10/48	11¾	174	1500	Remelt & Syrup	75.7	84.1	720	8	25.8	19.5	151.5	174	98.3	62.3	86.5	39.7	22.6	45	..	..
8-A	II-404	8/10/48	9¾	163	1500	Cut							163	95.6	61.9	91.7	42.2	19.7	36	..	..	..
9	III-407	8/11/48	11	171	1500	" " "	71.3	86.3*	720	8	...	21.0	154	171	96.7	59.7	92.6	40.8	18.9	50	16	16
9-A	II-408	8/11/48	10	164	1500	Cut							164	97.7	59.8	93.2	39.3	20.5	40	20	8	..
10	III-410	8/12/48	11½	172	1500	" " "	69.4	85.4	720	8	...	22.5	153.5	172	94.2	60.5	93.4	39.9	20.6	40	24	12
10-A	II-411	8/12/48	10	163	1500	Cut							163	96.7	60.5	93.1	39.1	21.4	35	21	11	..
11	III-416	8/16/48	12¼	172	1500	Remelt & Mol.	68.1	87.1	760	8	25.8	22.0	154	172	95.4	60.8	91.5	44.5	16.3	45	..	..
11-A	II-417	8/16/48	11	165	1500	Cut							165	93.1	60.3	91.0	42.0	18.3	30	..	..	..
19	III-461	8/31/48	9½	173	1500	" " "	71.7	83.3	720	8	25.8	23.0	153.5	173	96.7	60.4	92.3	41.6	18.8	45	15	..
19-A	II-462	8/31/48	8¾	162	1500	Cut							162	95.6	60.0	91.1	42.1	17.9	30	28	..	..
20	III-465	9/1/48	11	172	1500	" " "	70.8	86.6	720	8	25.8	22.5	153.0	172	94.0	61.4	93.3	40.9	20.5	45	16	..
20-A	II-466	9/1/48	10	163	1500	Cut							163	93.6	59.4	92.3	41.3	18.1	30	27	..	..
21	III-469	9/2/48	10	173	1500	" " "	66.3	84.8	780	8	25.9	26.0	156.5	173	94.4	58.0	89.8	38.8	19.2	45	14	..
21-A	II-470	9/2/48	10½	165	1500	Cut							165	95.2	58.3	93.2	39.5	18.8	30	19	..	..
22	III-472	9/3/48	13½	178	1500	" " "	67.2	86.2	760	8	25.9	25.5	156.5	178	96.5	58.9	89.5	38.3	20.6	45	..	..
22-A	II-473	9/3/48	10	169	1500	Cut							169	95.6	57.4	93.7	40.9	16.5	30	..	..	..

*Indicates hours massecuite in crystallizer when shrinkage and purity sample was obtained.

Boiling Technique—Data on Test Strikes at Ewa Plantation Co.																				
Massecuite Leaving Crystallizer											Purging and Final Molasses									
Hours in Cryst.	Lowest Temp. °F.	Re-heat Temp.	Shrink-age %	Special M. Liquor Pur.		Special Shrinkage %		Sug. Pur.	Ap. Pur.	Molasses Suc. Pur.	Ref. Den.	Total Ap. Pur. Drop	Cycle Min.	Reduc-ing Sugars	Ash	RS/A Ratio	Expect. Rf. Suc. Pur.	Points Above Expect.	Remarks	
92	...	...	...	...	..	..	..	76.8	30.7	38.09	93.9	23.8	50	21.07	14.16	1.49	33.01	5.08	————	
78	...	...	...	...	..	..	..	74.0	32.1	39.17	95.2	26.8	50	20.38	13.93	1.46	33.22	5.95	————	
96	...	...	...	...	..	..	..	64.4	29.4	37.26	92.7	29.3	50	21.07	13.74	1.53	32.76	5.50	False grain	
Boiling Technique—Data on Test Strikes at H. C. & S. Co. (Puunene)																				
108	...	...	...	...	..	..	..	...	39.3	....	87.5	28.4	50	....	....	...	....	...	————
110	...	...	...	44.2	24	..	..	81.5	37.8	43.37	89.8	27.1	50	13.89	18.06	.77	36.90	6.47	————	
166	...	...	...	50.8	6	..	..	66.8	38.4	44.13	89.2	28.1	50	13.54	16.10	.84	36.42	7.71	Excessive false grain	
158	...	...	...	44.1	72	..	..	79.9	39.6	46.06	89.5	24.4	50	13.54	15.98	.85	36.35	9.71	————	
103	...	...	...	37.3	72	..	..	71.7	37.1	43.54	91.2	26.3	50	13.72	16.26	.84	36.42	7.12	————	
Boiling Technique—Data on Test Strikes at Waialua Agric. Co.																				
56	120	128	...	...	..	..	..	77.7	28.4	34.74	94.0	28.6	50	....	....	1.45	33.49	1.25	————	
54	120	128	...	...	..	..	..	81.4	29.9	36.75	90.6	26.0	50	20.88	15.05	1.39	33.90	2.85	————	
44	120	128	...	...	..	..	..	87.5	29.8	36.50	90.50	27.5	50	....	....	1.41	33.76	2.74	————	
Boiling Technique—Data on Test Strikes at Oahu Sugar Co.																				
20	124	128	25	31.7	12	16	12	87.5	30.3	35.87	92.0	31.9	40	28.11	13.11	2.14	28.77	7.10	Exploratory	
36	116	128	28.5	...	..	..	..	88.4	28.4	36.03	91.6	29.5	40	29.53	12.39	2.38	28.13	7.90	"	
36	114	128	21.0	...	..	22.5	17	89.6	30.8	37.78	90.8	32.6	40	27.96	12.32	2.27	28.40	9.38	"	
60	116	130	19.0	31.8	17	17	17	85.1	29.3	34.11	92.6	31.9	40	27.35	13.50	2.03	29.13	4.98	"	
24	116	130	...	35.7	18	21	11	89.9	29.4	35.65	88.5	30.7	40	20.85	12.90	1.62	30.83	4.82	"	
24	114	130	18.0	33.2	24	18	24	80.4	29.9	36.16	92.3	35.5	40	21.02	13.20	1.59	31.00	5.16	"	
72	112	130	20.0	32.8	12	22	12	91.0	29.1	34.88	90.5	33.3	40	26.15	12.80	2.04	29.11	5.77	Water in crystallizer	
67	119	130	25.0	...	..	..	..	84.3	28.3	34.11	92.0	33.1	40	26.77	12.91	2.07	29.00	5.11	" " "	
61	112	130	22.0	30.7	20	..	..	88.0	27.4	33.20	92.8	35.9	40	28.11	13.09	2.15	28.74	4.46	" " "	
64	114	130	...	32.7	12	25	12	...	29.2	34.71	90.8	33.9	40	26.36	12.49	2.11	28.86	5.85	" " "	
29	116	130	23.0	31.3	17	..	..	84.9	29.5	34.52	92.4	32.4	40	26.11	13.00	2.01	29.20	5.32	" " "	
34	115	130	25.0	33.0	17	..	..	82.5	30.9	35.90	92.0	31.5	40	25.97	12.63	2.06	29.03	6.87	Syrup tank, overflow to crystallizer	
24	118	130	...	...	..	..	..	90.8	31.0	36.41	91.7	31.3	40	24.99	12.75	1.96	29.37	7.04	" " "	
27	117	130	22.0	...	..	..	..	84.4	31.6	36.50	91.1	30.3	40	24.42	12.81	1.91	29.54	6.96	" " " " "	
29	118	130	...	31.8	12	..	..	84.4	28.7	34.42	93.2	31.0	40	25.35	13.74	1.85	29.77	4.65	" " " " "	
84	114	130	...	...	..	..	..	91.3	30.7	36.12	91.3	29.1	40	24.53	13.05	1.88	29.65	6.47	Water in crystallizer	
78	114	130	23.0	...	..	..	..	82.5	28.4	34.41	91.7	32.1	40	25.47	12.93	1.97	29.34	5.07	" " "	
80	112	130	22.0	...	..	..	..	87.5	27.1	33.31	92.5	33.4	40	26.11	13.21	1.98	29.31	4.00	" " "	
27	115	130	...	...	..	..	..	87.1	31.5	...	92.3	29.3	40	....	....	...	....	...	" " "
24	122	130	...	...	..	..	..	88.2	34.2	...	89.9	26.1	40	....	....	...	....	...	" " "
35	119	130	15.0	32.6	18	15	18	81.3	30.6	36.09	93.8	29.8	35	25.21	14.10	1.79	30.01	6.08	" " "	
34	116	130	25.5	...	..	..	..	79.4	29.6	36.51	93.2	30.4	35	24.65	14.05	1.75	30.19	6.32	" " "	
33	117	130	16	32.0	18	17	18	78.9	29.1	35.66	93.2	32.3	35	25.35	14.77	1.72	30.33	5.33	" " "	
36	116	130	23.0	...	..	..	..	86.3	30.9	37.17	92.9	28.5	35	24.74	14.22	1.74	30.24	6.93	" " "	
39	117	130	...	...	..	..	..	78.8	30.0	...	...	28.0	35	...	...	...	...	...	Water in crystallizer	
90	113	130	...	...	..	..	..	...	28.1	35.90	92.9	30.2	35	24.16	14.27	1.69	30.47	5.43	" " "	
83	114	130	80.8	26.6	34.34	93.5	32.3	35	25.33	14.64	1.73	30.28	4.06	" " "	
84	115	130	84.5	27.8	35.09	93.5	29.6	35	24.74	14.40	1.72	30.33	4.76	" " "	

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PATHOLOGY

J. P. MARTIN.....	<i>Pathologist</i>	H. KOIKE.....	<i>Laboratory Technician</i>
	C. A. WISMER.....		<i>Associate Pathologist</i>

PHYSIOLOGY AND BIOCHEMISTRY

G. O. BURR.....	<i>Physiologist and Biochemist</i>	H. P. KORTSCHAK.....	<i>Associate Biochemist</i>
F. M. ASHTON.....	<i>Assistant Biochemist</i>	A. R. LAMB.....	<i>Associate Biochemist</i>
ADA FORBES.....	<i>Assistant Physiologist</i>	DAVID TAKAHASHI.....	<i>Assistant Biochemist</i>
CONSTANCE E. HARTT.....	<i>Associate Physiologist</i>	T. TANIMOTO.....	<i>Assistant Biochemist</i>

SUGAR TECHNOLOGY

J. H. PAYNE.....	<i>Technologist</i>	H. S. IWATA.....	<i>Laboratory Technician</i>
H. A. COOK.....	<i>Associate Technologist</i>	WILLIAM KENDA.....	<i>Associate Technologist</i>
F. J. DUPIN.....	<i>Scale Inspector</i>	L. J. RHODES.....	<i>Assistant Technologist</i>
A. C. FONG.....	<i>Laboratory Technician</i>	RAY SPELLMAN.....	<i>Laboratory Technician</i>
R. K. HAMILTON.....	<i>Assistant Technologist</i>	CARL SWANHOLM.....	<i>Laboratory Technician</i>

TRAINING OF PERSONNEL

J. D. BOND.....	<i>Coordinator</i>	DAVID TWIGG-SMITH.....	<i>Assistant-in-Training</i>
WILLIAM B. CASE.....	<i>Assistant-in-Training</i>	H. A. WADSWORTH.....	<i>Collaborator-in-Irrigation</i>
WILLIAM O. GILL.....	<i>Assistant-in-Training</i>	LETCHER WIGINGTON JR.....	<i>Assistant-in-Training</i>
PAUL V. HEYD.....	<i>Assistant-in-Training</i>	DAVID P. YOUNG.....	<i>Assistant-in-Training</i>

